Wireless Networks
Advanced Technology in Radio Communications

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Wireless Networks

Summary/Index

1. Introduction to wireless networks (1)

- Transmission media: radio frequency and infrared light.
- Radio frequency: narrowband or wide spectrum (wideband).
- Infrared light: short aperture systems (line of sigh) or high aperture (diffused systems).

1. Introduction to wireless networks (2)

- Advantages and disadvantages:
  – Advantages:
    - Mobility, Simplicity and quickly installation, flexibility, design, scalability, solidness .
  - Disadvantages:
    - Quality of service, price, propietary solutions, restrictions, security.

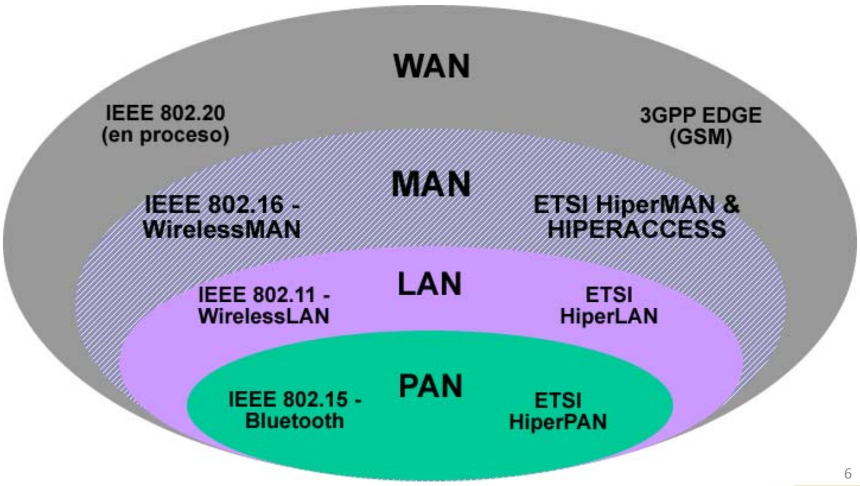
1. Introduction to wireless networks (3)

- Applications:
  - Hospitals
  - Small work groups
  - Dinamic environments
  - Educational establishments
  - Universities
  - Corporations

Lesson 7: wireless networks

1. Introduction to wireless networks (4)

Universal wireless standards



1. Introduction to wireless networks (5)
- Wireless LAN standards

Standard	Status	What it defines
IEEE 802.11	Finished in1997	Original standard of WLAN. It allows from1 to 2 Mbps
IEEE 802.11a	Finished in1999	High speed WLAN standard, it uses the 5 GHz band. It permits 54 Mbps
IEEE 802.11b	Finished in1999	WLAN standard, permits 11 Mbps.
IEEE 802.11c	Finished in 2001	Wireless networks use as bridges, included in 802.11d .
IEEE 802.11d	Finished in 2001	International wireless networks (roaming).
IEEE 802.11e	Finished in 2005	It allows real time data in every type of environment and situations because of QoS mechanism with HCF (Hybrid Fibre Coaxial)
IEEE 802.11f	Finished in 2003	It defines communication between two access points.
IEEE 802.11g	Finished in 2003	Alternative high speed WLAN standard in 2,4 GHz band. It permits over 20 Mbps.
IEEE 802.11h	Finished in 2003	It defines technical management for 802.11a (coexistence with satellites and radar),it applies DFS and TPC

1. Introduction to wireless networks (6)

Standard	Status	What it defines
IEEE 802.11i	Finished in 2004	Specific security functions for wireless networks that work alongside IEEE 802.1x
IEEE 802.11j	Finished in 2004	Japan extension standard 802.11h
IEEE 802.11k	Finished in 2008	It allows switches and wireless access points to calculate and to value the customer radio frequency resorts
IEEE 802.11l	In process	Reserved
IEEE 802.11m	Finished in 2007	Standard maintenance
IEEE 802.11n	Finished in Dec. 2009	Speed transmission improve with MIMO
IEEE 802.11o	In process	Reserved
IEEE 802.11p	Finished in Jul 2010	WAVE standars with DSRC in 5,9 GHz band
IEEE 802.11r	In process	Quick roaming (it allows VoIP with delays less than 50 ms)
IEEE 802.11s	In process	Interoperability between manufacturer protocols of Mesh equipment
IEEE 802.11w	Finished in December, 2009	It improves authentication and codification protocol security
IEEE 802.11ac	In progress	Increasing the channel bandwidth, modulation and MIMO vs 802.11n
IEEE 802.11ad	In progress	It operated in the 60 GHz band, speed rate up to 6.75 Gbps

1. Introduction to wireless networks (7)

- 2.4 GHz band interferences:
  - Microwave oven.
  - Neighbor bands :
    - Co-channel interference.
    - Another neighbour networks : WLAN DSSS, FHSS, Bluetooth.

2. WMAN: IEEE 802.16.

- 2.1. Introduction to WiMAX
- 2.2. WiMAX characteristics
- 2.3. WiMAX frequency bands
- 2.3. WiMAX working
- 2.4. WiMAX applications

2.1. Introduction to WiMAX

- WiMAX → 'Worldwide Interoperability for Microwave Access'
- WiMAX is the commercial name of IEEE 802.16 standard
- It allows speeds near to ADSL and cable ones, but wireless
- It has a huge range
- WiMAX is basically intented for "last mile" technology
- It can be used for access links, MAN or even for WAN

2.1. Introduction to WiMAX

- WiMAx technology will be the base station of Internet access Metropolitan networks
- It will be a support in order to make easily connections in rural areas
- It will be used in business area in order to implement internal communications
- Their popularity will suppose a definitive deployment of other technologies, such as VoIP

2.2. WiMAX characteristics

- Low cost introduction
- Huge range, up to 50 Km
- Transmission speeds can reach 75 Mbps
- It does not require Line of Sight (NLOS)
- It is avaliable with voice and video characteristics
- IP technology coast to coast
- In function of the used channel bandwidth, a base station can support a few thousand users

Lesson 7: wireless networks

2.2. WiMAX characteristics

- Bandwidth channels from 1,5 to 20 MHz
- It uses OFDM and OFDMA modulations with 256 and 2048 carriers respectively
- It adds "smart antennas" support technology that improve coverage and efficiency
- It includes adaptive modulation mechanisms in function of radio link characteristics

2.2. WiMAX characteristics

- It supports few hundred users per channel, with a high bandwidth and it is suitable both to constant traffic and burst one
- It supports multiple services simultaneously offering QoS in 802.16e
- It has the possibility of create mesh networks for a full communication between users, without line of sight needs.
- In security characteristics it has user authentication measures and data encryption through 3DES and RSA algorithm

2.2. WiMAX characteristics

- IEEE 802.16 → It is the standard core. It specifies MAC layer and PTMP radio communications in range frequency from 10 to 66 GHz, it needs line of sight, with a capacity up to 134 Mbps in cells from 2 to 5 km. It was published in April of 2002.
- IEEE 802.16a → Standard 802.16 extension towards bands from 2 to 11 GHz, with NLOS and LOS systems, and PTP and PTMP protocols. It was published in April of 2003.
- IEEE 802.16d → standard 802.16a extension, it reaches speeds up to 134 Mbps. It was published in Juny of 2004.
- IEEE 802.16e → 802.16 extension that includes wide band connections for mobile devices. It was published in December of 2005

2.2. WiMAX characteristics

- Comparative table of the more significant IEEE 802.16 versions

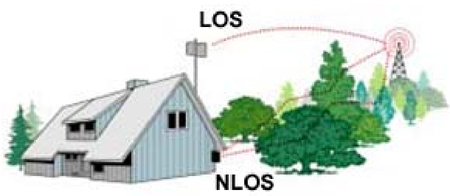
	802.16/REVc	802.16a/REVd	802.16e
Spectrum	10 - 66 GHz	< 11 GHz	< 6 GHz
Working	Only with line of sight	No line of sight (NLOS)	No line of sight (NLOS)
Bit rate	32 - 134 Mbit/s with 28 MHz channels	Up to 75 Mbit/s with 20 MHz channels	Up to15 Mbit/s with 5 MHz channels
Modulation	QPSK, 16QAM and 64 QAM	OFDM with 256 subcarriers QPSK, 16QAM, 64QAM	The same than 802.16a
Mobility	Fixed system	Fixed system	Pedestrian mobility
Bandwidth	20, 25 and 28 MHz	Selectable between 1,5 and 20 MHz	The same than 802.16a with the uplink channels to save power
Typical radius cell	2 - 5 km approx.	5 - 10 km approx. (maximum reach about 50 km)	2 - 5 km approx.

2.2. WiMAX characteristics

WiMAX version	Motivation	Maximum coverage	Frequency range	Comments
802.16	First version	5 km	10 – 66 GHz	Just for an only carrier with LOS (SC)
802.16a	It includes NLOS	50 km	2 – 11 GHz	Three new radio interfaces:an only carrier with NLOS (SCa), OFDM 256 and OFDMA 2048
802.16b	In order to deal with unlicensed frequency bands (WirelessHUMAN)	Undefined	5 – 6 GHz	It includes QoS in real time video and voice.
802.16c	In order to create LOS system profiles	50 km	10 – 66 GHz	It updates and completes first standar version
802.16d	In order to perfects 802.16a	50 km	2 – 11 GHz	It replaces all previous versions
802.16e	In order to includes mobility in standard one	5 km	2 – 6 GHz	With maximum speeds of mobile telephone about 250 km/h
802.16f *	It includes multi-hop functionality	------	------	It allows to create Ad-Hoc networks
802.16g *	It includes an efficient handover	------	------	It pretends to improve QoS
802.16m*	Theorical speed of 1 GB.	------	------	It allows 100 Mbps in mobile environment

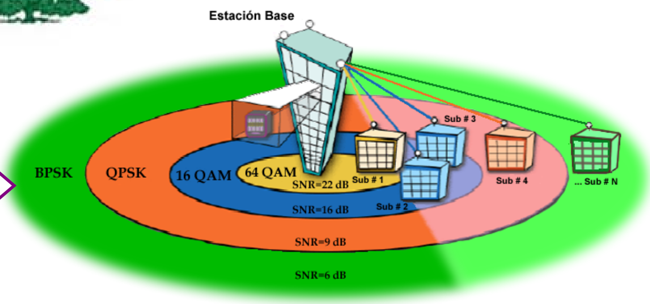
(*) undeveloped

2.2. WiMAX characteristics



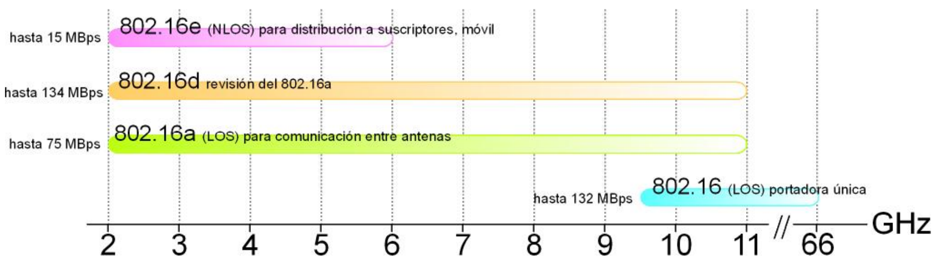
LOS (Line of sight) and NLOS (no line of sight)

Uses of the different modulations



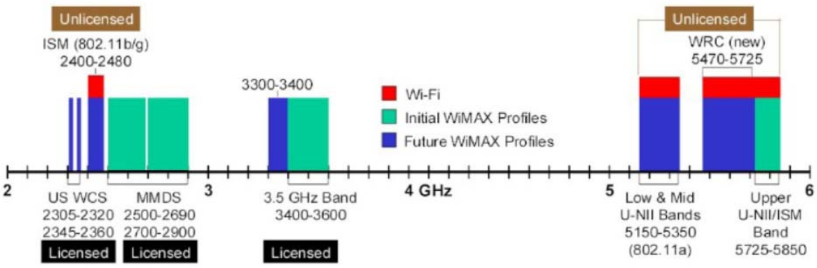
2.3. WiMAX frequency band

- WiMAX spectrum



2.3. WiMAX frequency band

⌘802.16e spectrum



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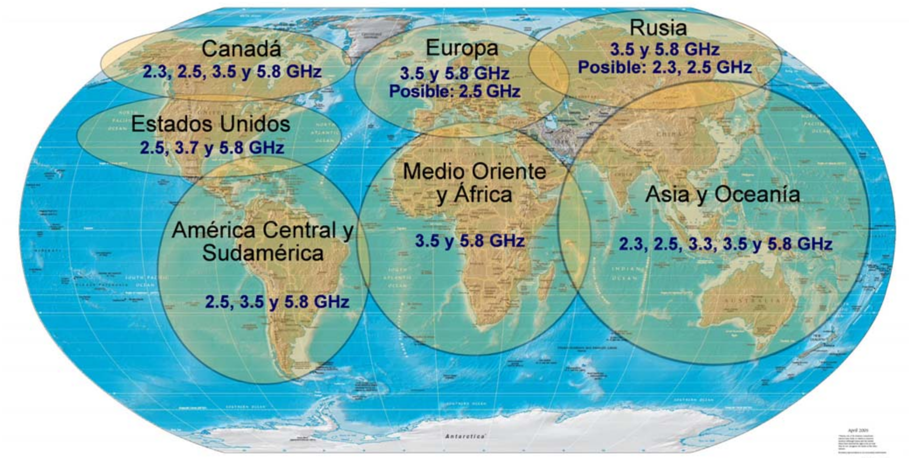
2.3.WiMAX frequency band

- Deployment of primary bands for WiMAX



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2.3. WiMAX frequency band

- Frequency channels for some european countries

Country	Partition (MHz)	Spectrum assigned
Denmark	3410 -- 3590	2 licences of 2 x 26,5 MHz 1 licence of 27 MHz
Germany	3410 -- 3580	5 duplex blocks x 14 MHz every one
Ireland	3410 -- 3435 / 3510 -- 3535 3475 -- 3500 / 3575 -- 3600	2 x 25 MHz every one
The Netherlands	3500 -- 3580	80 MHz just TDD
Sweden	3400 -- 3600	3 licences of 2 x 28 MHz

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2.3. WiMAX frequency band

- Channel bandwidth for Europe

Frequency band	Multiplexation	Channel bandwidth
3,5 GHz	FDD or TDD	3,5 MHz and 7 MHz (14 MHz in the future)
5,8 GHz	TDD	10 MHz

2.3. WiMAX frequency band

- TDD vs FDD

	TDD	FDD
Advantages	- Efficient RF spectrum - Asymmetric traffic - No duplexer needed - Easy use of "smart antennas"	- Proved voice technology - Symmetric traffic - No guard time needed
Disadvantages	- It cannot transmit and receive at the same time - More expensive filter - It is not possible to situate two TDD sectors at the same communication pylon if they use neighbour bands	- Duplexer needed - Spectrum usually needs license - High cost due to spectrum shopping

2.3. WiMAX frequency band

- Wireless channels of fixed bandwidth
  - Cells with less than 10 km of radius
  - In receiver we implement omnidirectional antennas (2-10 m) in windows or roofs
  - Base station antennas from 15 to 40 m
  - Types of ground variety and vegetation density

2.3. WiMAX frequency band

- Wireless channels of fixed bandwidth models
  - SUI models (Stanford University Interim):
    - Six channels collection for different types of ground
  - Ground categories
    - Type A: Great trees density (SUI-5, SUI-6)
    - Type B: Moderate trees density (SUI-3, SUI-4)
    - Type C: Low trees density (SUI-1, SUI-2)

Lesson 7: wireless networks

2.3. WiMAX frequency band

Example: extrapolated model for cells of 30 km

		Model of extrapolated channel - 30 km								
		SUI - 1			SUI - 2			SUI - 3		
	Units	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3
Delay	µs	0	1,19	2,68	0	1,2	3,3	0	1,2	2,7
Power (Omnidirectional antenna)	dB	0	-15	-20	0	-12	-15	0	-5	-10
K ratio 90%		2	0	0	1	0	0	0	0	0
K ratio 75%		7	0	0	4	0	0	2	0	0
Power (Antenna 30º)	dB	0	-21	-32	0	-18	-27	0	-11	-22
K ratio 90%		7	0	0	4	0	0	1	0	0
K ratio 75%		26	0	0	13	0	0	5	0	0

2.3. WiMAX frequency band

Example: extrapolated model for cells of 30 km (cont.)

		Model of extrapolated channel - 30 km								
		SUI - 4			SUI - 5			SUI - 6		
	Units	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3
Delay	µs	0	4,5	11,9	0	11,9	29,8	0	41,7	59,6
Power (Omnidirectional antenna)	dB	0	-4	-8	0	-5	-10	0	-10	-24
K ratio 90%		0	0	0	0	0	0	0	0	0
K ratio 75%		1	0	0	0	0	0	0	0	0
K ratio 50%					1	0	0	1	0	0
Power (Antenna 30º)	dB	0	-10	-20	0	-11	-22	0	-16	-36
K ratio 90%		1	0	0	0	0	0	0	0	0
K ratio 75%		2	0	0	1	0	0	1	0	0
K ratio 50%					3	0	0	2	0	0

2.3. WiMAX frequency band

Example: extrapolated model for cells of 50 km

		Model of extrapolated channel - 50 km								
		SUI - 1			SUI - 2			SUI - 3		
	Units	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3
Delay	µs	0	1,3	2,93	0	1,3	3,58	0	1,3	2,93
Power (Omnidirectional)	dB	0	-15	-20	0	-12	-15	0	-5	-10
K ratio 90%		1	0	0	1	0	0	0	0	0
K ratio 75%		5	0	0	3	0	0	1	0	0
Power (Antenna 30º)	dB	0	-21	-32	0	-18	-27	0	-11	-22
K ratio 90%		6	0	0	3	0	0	1	0	0
K ratio 75%		19	0	0	10	0	0	4	0	0

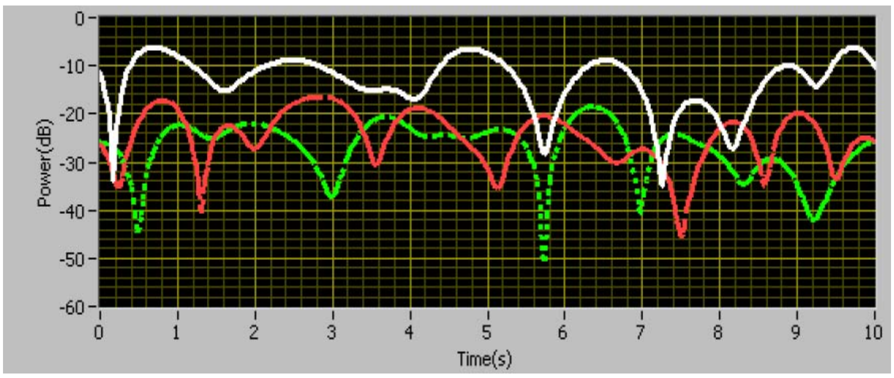
2.3. WiMAX frequency band

Example: extrapolated model for cells of 50 km (cont.)

		Model of extrapolated channel - 50 km								
		SUI - 4			SUI - 5			SUI - 6		
	Units	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3
Delay	µs	0	4,88	13,01	0	13,01	32,53	0	45,55	65,07
Power (Omnidirectional antenna)	dB	0	-4	-8	0	-5	-10	0	-10	-24
K ratio 90%		0	0	0	0	0	0	0	0	0
K ratio 75%		0	0	0	0	0	0	0	0	0
K ratio 50%					1	0	0	0	0	0
Power (Antenna 30º)	dB	0	-10	-20	0	-11	-22	0	-16	-36
K ratio 90%		0	0	0	0	0	0	0	0	0
K ratio 75%		2	0	0	1	0	0	1	0	0
K ratio 50%					2	0	0	2	0	0

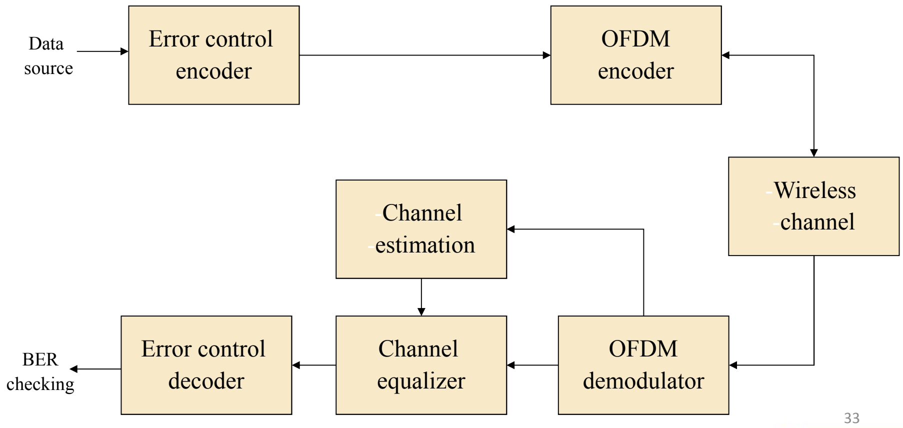
2.3. WiMAX frequency band

- Example: three beams sample for a SUI model



2.3. WiMAX working

- Physical layer block diagram of IEEE 802.16a



2.3. WiMAX working

- WiMax works like WiFi but with:
  - higher speeds
  - longer distances
  - for a higher number of users
- WiMax could resolve the lack of wide band access in suburban and rural areas that telephony and cable companies still does not offer.

2.3. WiMAX working

- A WiMax system has two parts:
  - WiMax communication towers → they cover up to 8.000 square km according to type of transmitted signal.
  - Receivers → cards that we connect to PC's , laptops, PDA's and another in order to have connection
- We have two types of forms to offering signal:
  - When there are objects that cover the line of sight between receiver and antenna
    In this case, we work with low frequencies (between 2 and 11 GHz) in order to do not have interferences because of objects. Of course, the bandwidth is less. Antennas that support this service cover 65 square km (similar to mobile telephone).
  - When there is nothing between receiver and antenna, line of sight.
    In this case, we work in very high frequencies, in the order of 66 GHz, having a great bandwidth. In addition, antennas that offer this service will cover up to 9.300 square km.

2.4. WiMAX applications

- Point to point or point to multipoint communications, fixed or mobile ones
- Products that provide high speed links
- WiMAX deployment in companies, up to 10 times cheaper than E1 or T1 links
- Rural area or under developed countries services
- Some LMDS suppliers have started to show their interest in WiMAX

3. WLAN: IEEE 802.11 and HIPERLAN/2

Summary

3.1. Introduction

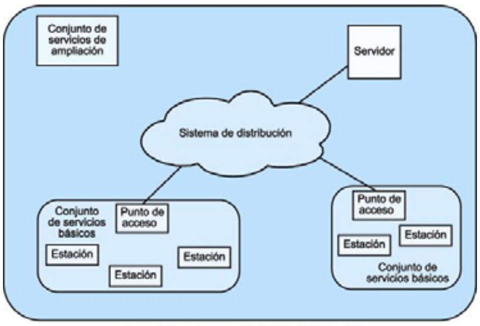
- IEEE 802.11:
  - Standard approved in 1997. Revised in 1999.
  - Similar to any 802 LAN cable regulation.
  - Air is the transmission medium.
  - Mobility chance.
  - It defines two layers:
    - Physical layer (infrared, FHSS, DSSS, OFDM, DSSS extension)
    - MAC layer

3.2. WLAN 802.11 architecture (1)

- It was designed in order to support a distributed structure between mobile stations
- Advantages :
  - Fault tolerance
  - Bottleneck elimination
  - Flexibility

3.2. WLAN 802.11 architecture (2)

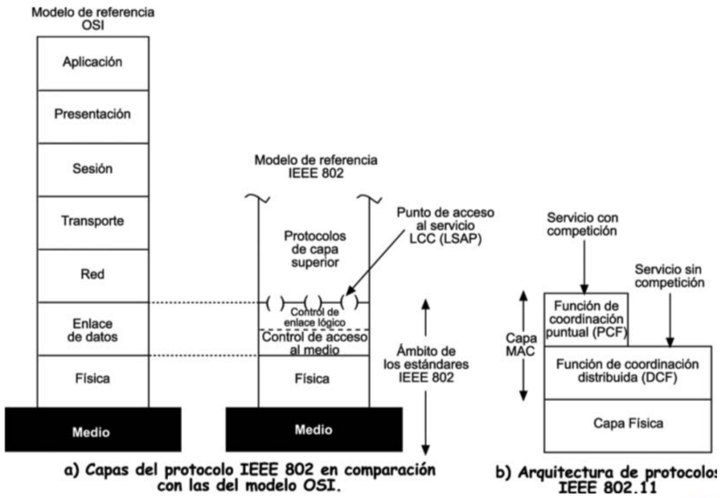
- Components:
  - Station
  - Access Point (AP)
  - Basic Service Set (BSS)
  - Distribution System (DS)
  - Extended Services Set (ESS)



Arquitectura IEEE 802.11

3.2. WLAN 802.11 architecture (3)

- Architecture



3.2 WLAN 802.11 architecture (4)

- Services

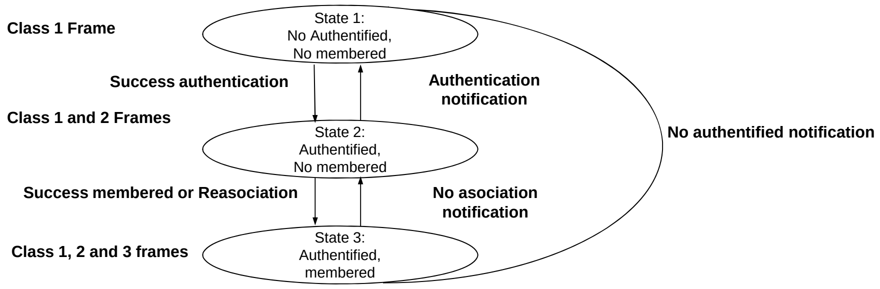
Servicios

Servicios de Estación
- Autentificación
- Desautentificación
- Privacidad
- Entrega de datos

Servicios de Distribución
- Asociación
- Desasociación
- Reasociación
- Distribución
- Integración

3.2. WLAN 802.11 architecture (5)

- Relation between states and services



3.3. Physical layer choice (1)

- Basic points in order to choose the appropiate technology:
  - Performance
  - Total network capacity
  - Overlapping
  - Fiability

3.3. Physical layer choice (2)

- Basic points in order to choose the appropiate technology:
  - Multipath interference
  - Security and encryptation
  - Coverage and costs

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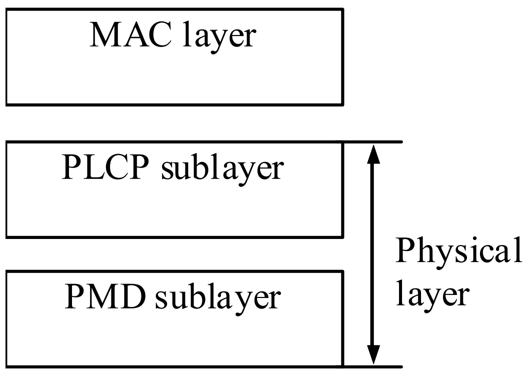
3.3. Physical layer choice (3)

- OSI model of physical layer



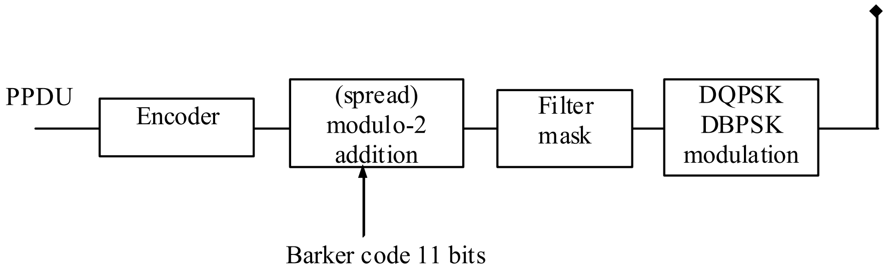
3.3. Physical layer choice (4)

Physical layer with DSSS technology

- DSSS → Direct Sequence Spread Spectrum
- 2.4 GHz frequency band
- RF transmission medium
- Data transmission over medium is controlled by DSSS PMD sublayer and managed by DSSS PLCP sublayer

3.3. Physical layer choice (5)

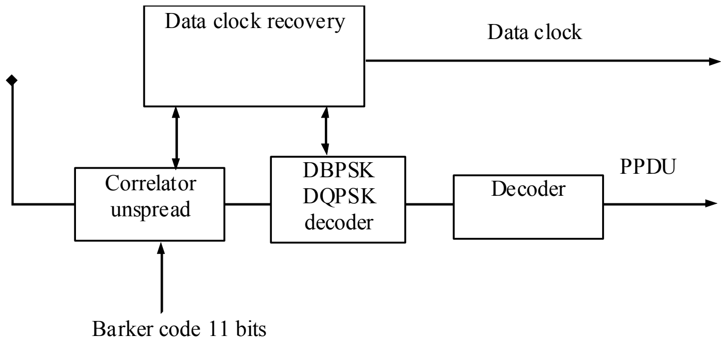
Physical layer with DSSS technology



PMD DSSS transmitter

3.3. Physical layer choice (6)

Physical layer with DSSS technology

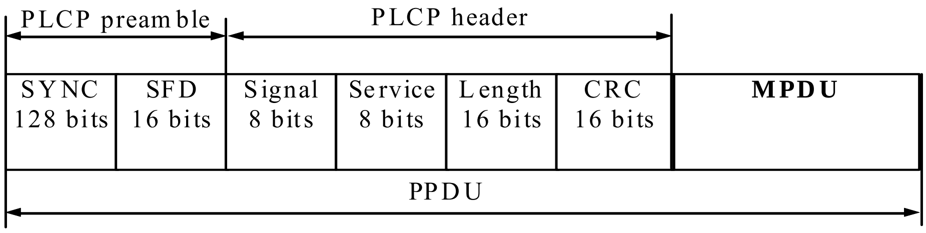


PMD DSSS receiver

3.3. Physical layer choice (7)

Physical layer with DSSS technology

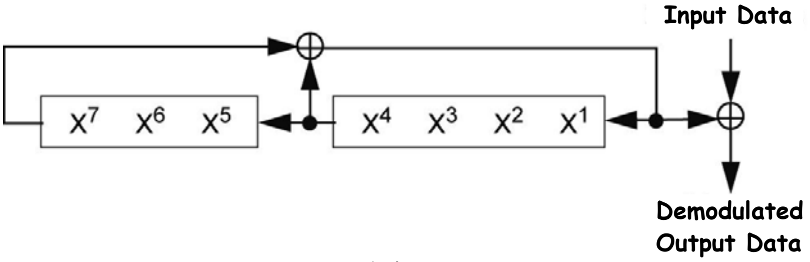
- PLCP DSSS sublayer



3.3. Physical layer choice (8)

Physical layer with DSSS technology

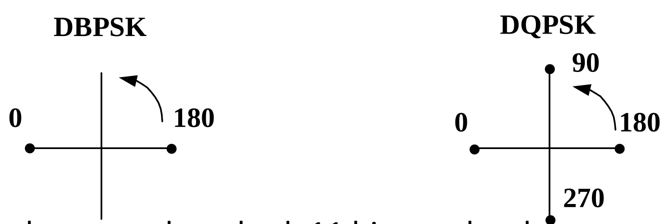
- PLCP DSSS sublayer
  - Data encoding: it uses a 7 bits polynomial. Randomized polynomial is: $G(z)=z^{-7}+z^{-4}+1$



3.3. Physical layer choice (9)

Physical layer with DSSS technology

- PLCP DSSS sublayer
  - DSSS modulation:

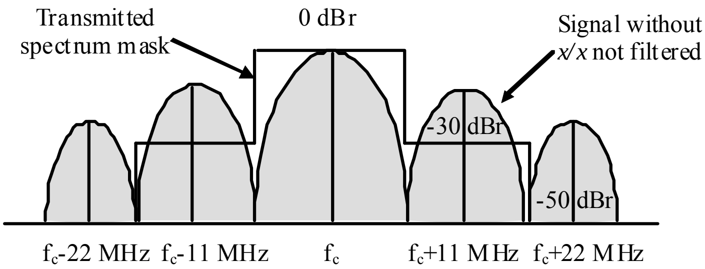


  - Barker spread method: 11 bits works, the sequence is: 1, -1, 1, 1, -1, 1, 1, 1, -1, -1, -1.

3.3. Physical layer choice (10)

Physical layer with DSSS technology

- PLCP DSSS sublayer
  - DSSS operative channels and transmitted power requirement

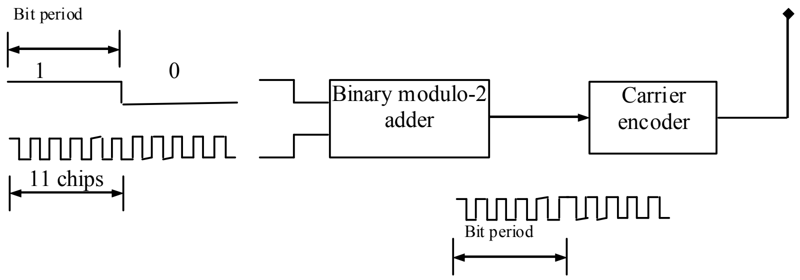


Transmitted spectrum mask

3.3. Physical layer choice (11)

Physical layer with DSSS technology

- PLCP DSSS sublayer
  - DSSS operative channels and transmitted power requirement



DSSS PMD transmitter

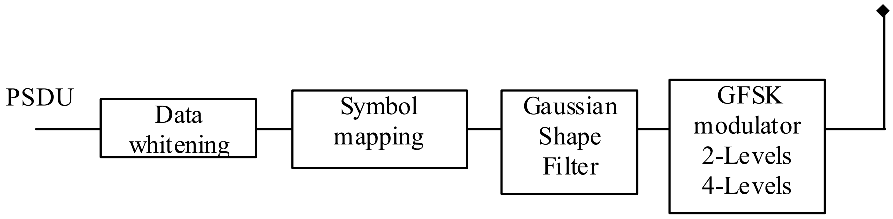
3.3. Physical layer choice (12)

Physical layer with DSSS technology

- FHSS → Frequency hopping Spread Spectrum
- 2.4 GHz frequency band
- RF transmission medium
- Data transmission is managed by FHSS PMD sublayer and it convert into RF signals for the wireless medium, by using carrier modulation and FHSS techniques.

3.3. Physical layer choice (13)

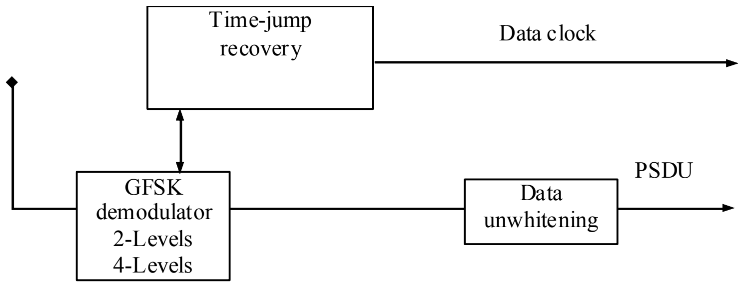
Physical layer with DSSS technology



PMD FHSS transmitter

3.3. Physical layer choice (14)

Physical layer with DSSS technology

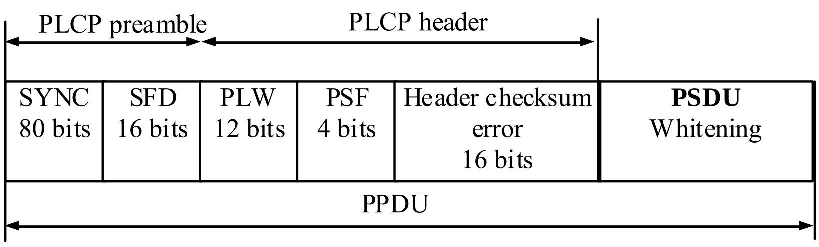


FHSS PMD receiver

3.3. Physical layer choice (15)

Physical layer with DSSS technology

- PLCP FHSS sublayer



3.3. Physical layer choice (16)

Physical layer with DSSS technology

- PLCP FHSS sublayer
  - PSF bit assignment for PSDU data range

Bit 1-3	Rango de datos - Mbps
000	1.0
001	1.5
010	2.0
011	2.5
100	3.0
101	3.5
110	4.0
111	4.5

3.3. Physical layer choice (17)

Physical layer with DSSS technology

- PLCP FHSS sublayer
  - PSDU data whitening: it applies to PSDU before of the transmission. It uses $S(x) = x^7 + x^4 + 1$ polynomial.
  - FHSS modulation: two levels GFSK modulation.

    1 Binary = $f_c + f_d$

    0 Binary = $f_c – f_d$

    optionally, it exists four levels GFSK modulation.

3.3. Physical layer choice (18)

Physical layer with DSSS technology

- PLCP FHSS sublayer
  - FHSS conmuted channel:
    - Frequencies for a number of geographical location

USA and Europe: 79 jump channels (minimum 75)

Japan: 23 jump channels (minimum 20)

3.3. Physical layer choice (19)

Physical layer with DSSS technology

- PLCP FHSS sublayer
- FHSS conmuted channel:

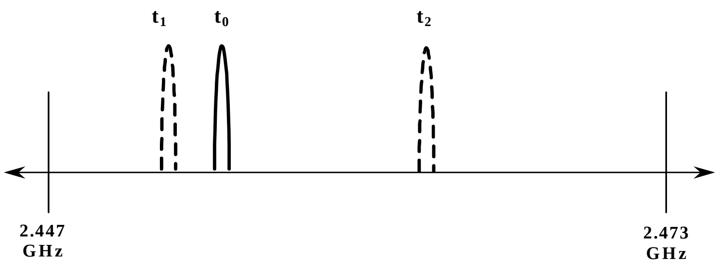
Documents that specifies requirements

Region	Approved Standards	Documents	Approved Authority
Europe	ETSI (European Telecommunications Standards Institute)	ETS 300-328 ETS 300 -339	National Authorities
France	ETSI Feb. 1995	SP/DGPT/ATAS/23 ETS 300-328 ETS 300 -339	Telecommunications and Post Office
Japan	ARIB (Association of Radio Industries Business)	RCR STD-33A	Ministry of Telecommunications
North America	IC (Industry of Canada) FCC (Federal Communications Commission)	GL36 CFR47 , part 15, sections 15.205, 15.209, 15.247	IC FCC
Spain	BOE nº 164 (10-7-1991, revised 25-6-1995)	ETS 300-328 ETS 300 -339	CNAF

3.3. Physical layer choice (21)

Physical layer with DSSS technology

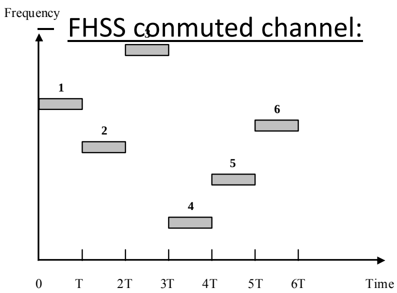
- PLCP FHSS sublayer
  - FHSS conmuted channel:
    - Power spectral density for FHSS



3.3. Physical layer choice (22)

Physical layer with DSSS technology

- PLCP FHSS sublayer
  - FHSS conmuted channel:



⌘FH pattern example:
- Hop for every time slot.
- It uses all frequency spectrum.

3.3. Physical layer choice (23)

Physical layer with DSSS technology

- PLCP FHSS sublayer
  - FHSS conmuted channel:
    - *United States and Europe*
    - Set 1: (0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, 45, 48, 51, 54, 57, 60, 63, 66, 69, 72, 75)
    - Set 2: (1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 43, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73, 76)
    - Set 3: (2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, 44, 47, 50, 53, 56, 59, 62, 65, 68, 72, 74, 77)
    - *Japan*
    - Set 1: (6, 9, 12, 15)
    - Set 2: (7, 10, 13, 16)
    - Set 3: (8, 11, 14, 17)

3.4. MAC layer (1)

WLAN 802.11 standard topology

From one end to the other

Customer and access point

3.4. MAC layer (2)

WLAN 802.11 standard topology

Multiple AP’s and roaming

Extension point

3.4. MAC layer (3)

WLAN 802.11 standard topology

Use of directional antennas

3.4. MAC layer (4)

WLAN access mechanism

Two different protocols:

- Assignment protocols:
  - FDMA
  - TDMA
  - CDMA

3.4. MAC layer (5)

WLAN access mechanism

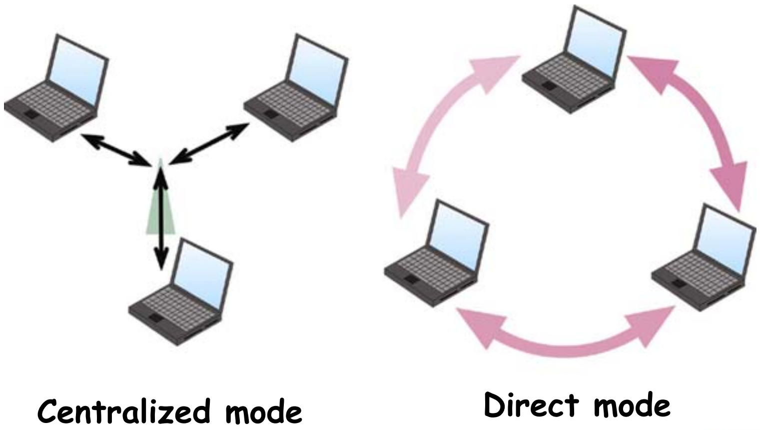
Two different protocols:

- Collision protocols:
  - CSMA/CD
  - CSMA/CA

3.5. Introduction to Hiperlan/2 (1)

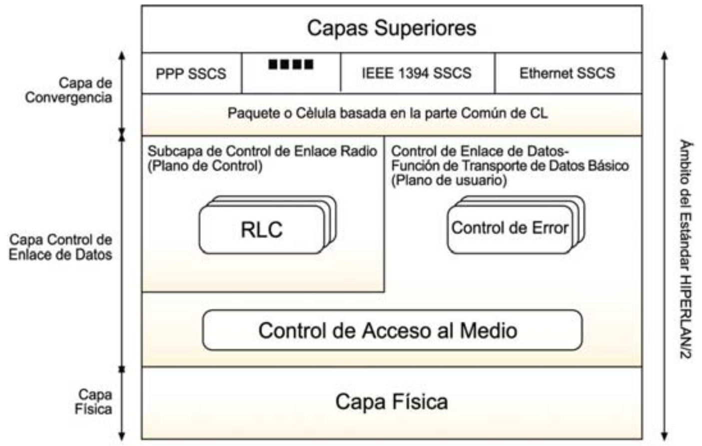
- HIPERLAN/2: High PErformance Radio Local Area Network type 2
- Standard developed in Europe
- 5 GHz frequency band
- Speed rate from 6 to 54 Mbps
- OFDM modulation
- Two basic modes of work:
  - Centralized mode
  - Direct mode

3.5. Introduction to Hiperlan/2 (2)



3.5. Introduction to Hiperlan/2 (3)

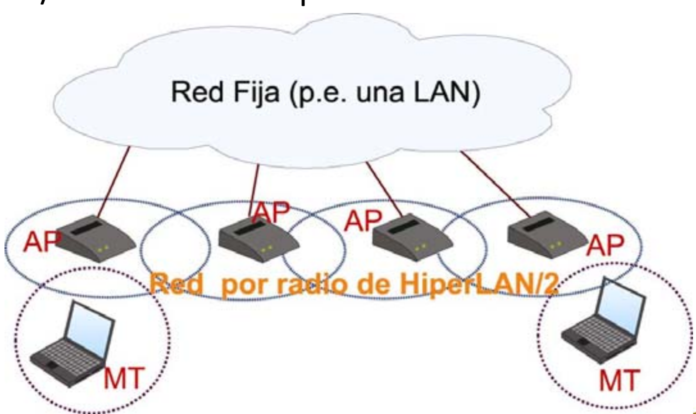
- Reference model



Arquitectura del protocolo HIPERLAN/2

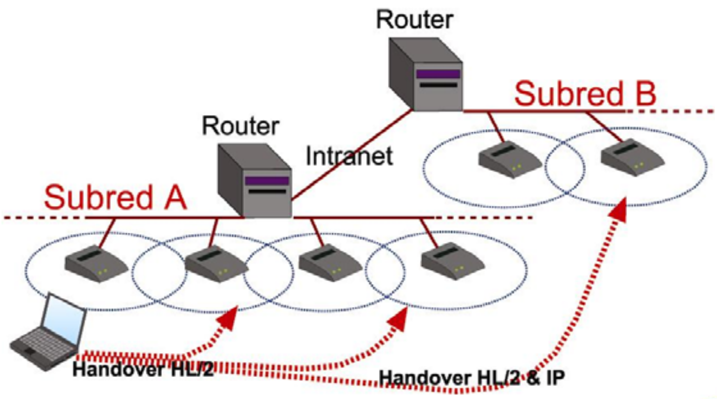
3.5. Introduction to Hiperlan/2 (4)

- HL/2 network topology
  - HL/2 network example



3.5. Introduction to Hiperlan/2 (5)

- HL/2 network topology
  - HL/2 application example



3.5. Introduction to Hiperlan/2 (6)

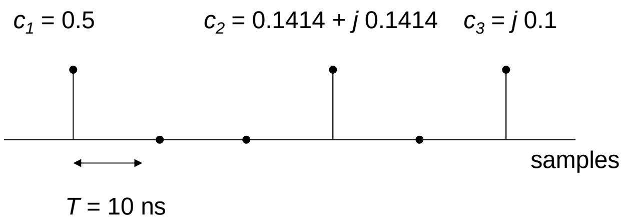
<u>Multipath channel</u>

- Receiver does not detect an only transmitter signal
- Characterization: obtaining of the impulse response.
- Relative relay of the different paths is defined by complex value location (Rayleigh distribution).

3.5. Introduction to Hiperlan/2 (7)

Multipath channel

- Multipath impulse response example



3.5. Introduction to Hiperlan/2 (8)

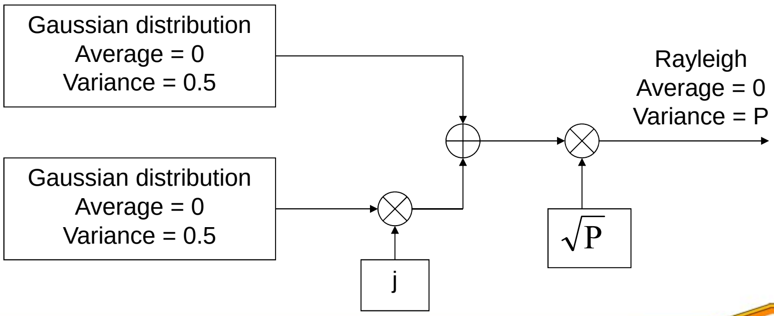
Multipath channel

- Multipath impulse response example
  - In this vector, null samples show time samples where do not receive any signal sample.
  - Specific value collection that is assigned to this coefficients, relation between them and the temporal distribution is what we known as power channel profile.

3.5. Introduction to Hiperlan/2 (9)

Multipath channel

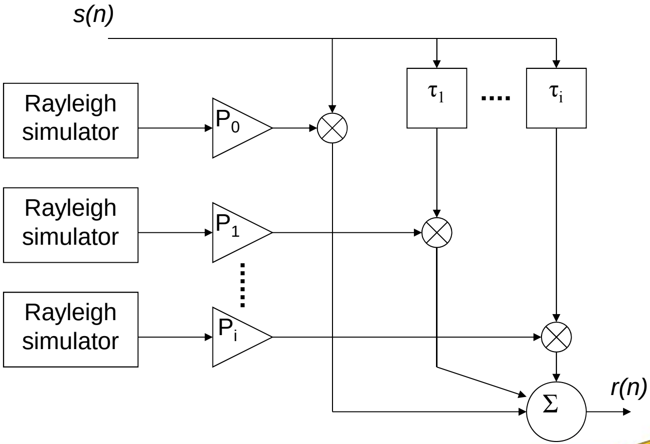
- Rayleigh distribution obtaining



3.5. Introduction to Hiperlan/2 (10)

Multipath channel

- multipath effect simulator



3.5. Introduction to Hiperlan/2 (11)

Doppler effect

- Definition: frequency change (or wavelength) from a wave, caused by a time rate variation in effective path length between observation point and origin one.

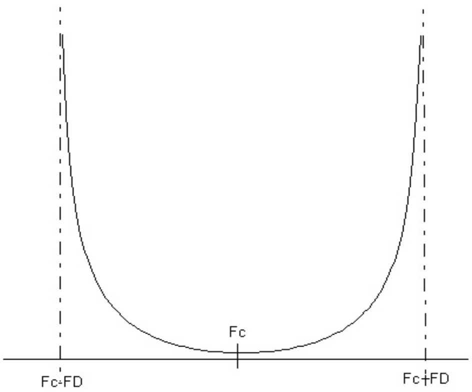
3.5. Introduction to Hiperlan/2 (12)

Doppler effect

- Relative movement between access point and mobile terminal is traduced in a random frequency modulation caused by the different Doppler movements that appear in multipath channel components.

3.5. Introduction to Hiperlan/2 (13)

Doppler effect



3.5. Introduction to Hiperlan/2 (14)

Doppler effect

- It is described like a method that consist in filter Rayleigh values of every multipath component using a filter with a spectrum adequate to the expression

$$D(f) = \frac{1}{\sqrt{1-(f/f_D)^2}}$$

3.5. Introduction to Hiperlan/2 (15)

Doppler effect

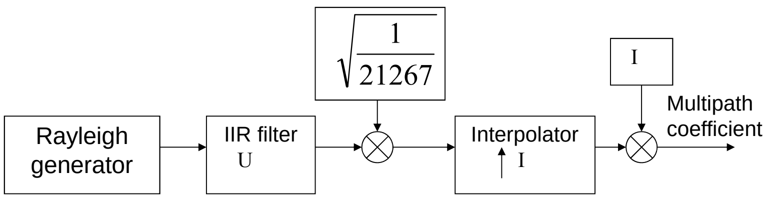
- IIR filter coefficients

Poles
0.99015456438065 ± j 0.04500919952989
0.98048448562622 ± j 0.01875760592520
0.99652880430222 ± j 0.05493839457631
0.99827980995178 ± j 0.05666938796639
Zeros
0.99835836887360 ± j 0.05727641656995
0.99744373559952 ± j 0.07145611196756
0.99440407752991 ± j 0.10564350336790
0.96530824899673 ± j 0.26111298799575

3.5. Introduction to Hiperlan/2 (16)

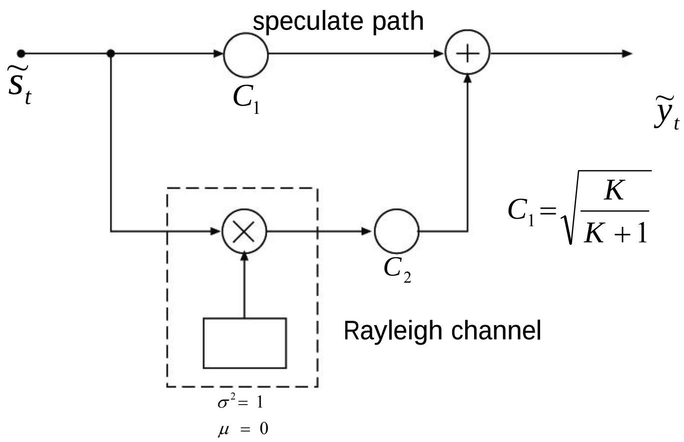
Doppler effect

- multipath coefficients generator



3.5. Introduction to Hiperlan/2 (17)

Rice channel simulation model



$$C_1 = \sqrt{\frac{K}{K+1}} \qquad C_2 = \frac{1}{\sqrt{K+1}}$$

3.5. Introduction to Hiperlan/2 (18)

Channel models

- Inside the BRAN project it is defined a serie of channel models with rms values of temporal diffusion of 50 ns, 100 ns, 150 ns and 250 ns.
- Most of multipath coefficients have a Rayleigh distribution.

3.5. Introduction to Hiperlan/2 (19)

Channel models

Coeficiente	Retardo (ns)	Potencia media relativa (dB)
1	0	0.0
2	10	-0.9
3	20	-1.7
4	30	-2.6
5	40	-3.5
6	50	-4.3
7	60	-5.3
8	70	-6.1
9	80	-6.9
10	90	-7.8
11	110	-4.7
12	140	-7.3
13	170	-9.9
14	200	-12.5
15	240	-13.7
16	290	-18.0
17	340	-22.4
18	390	-26.7

-Type A channel model

Coeficiente	Retardo (ns)	Potencia media relativa (dB)
1	0	-2.6
2	10	-3.0
3	20	-3.5
4	30	-3.9
5	50	0.0
6	80	-1.3
7	110	-2.6
8	140	-3.9
9	180	-3.4
10	230	-5.6
11	280	-7.7
12	330	-9.9
13	380	-12.1
14	430	-14.3
15	490	-15.4
16	560	-18.4
17	640	-20.7
18	730	-24.6

-Type B channel model

3.5. Introduction to Hiperlan/2 (20)

Channel models

Coeficiente	Retardo (ns)	Potencia media relativa (dB)
1	0	-3.3
2	10	-3.6
3	20	-3.9
4	30	-4.2
5	50	0.0
6	80	-0.9
7	110	-1.7
8	140	-2.6
9	180	-1.5
10	230	-3.0
11	280	-4.4
12	330	-5.9
13	400	-5.3
14	490	-7.9
15	600	-9.4
16	730	-13.2
17	880	-16.3
18	1050	-21.2

-Type C channel model

Coeficiente	Retardo (ns)	Potencia media relativa (dB)
1	0	0.0
2	10	-10.0
3	20	-10.3
4	30	-10.6
5	50	-6.4
6	80	-7.2
7	110	-8.1
8	140	-9.0
9	180	-7.9
10	230	-9.4
11	280	-10.8
12	330	-12.3
13	400	-11.7
14	490	-14.3
15	600	-15.8
16	730	-19.6
17	880	-22.7
18	1050	-27.6

-Type D channel model

Coeficiente	Retardo (ns)	Potencia media relativa (dB)
1	0	-4.9
2	10	-5.1
3	20	-5.2
4	40	-0.8
5	70	-1.3
6	100	-1.9
7	140	-0.3
8	190	-1.2
9	240	-2.1
10	320	0.0
11	430	-1.9
12	560	-2.8
13	710	-5.4
14	880	-7.3
15	1070	-10.6
16	1280	-13.4
17	1510	-17.4
18	1760	-20.9

-Type E channel model

3.6. Physical layer description of HIPERLAN/2

- Transceiver block diagram

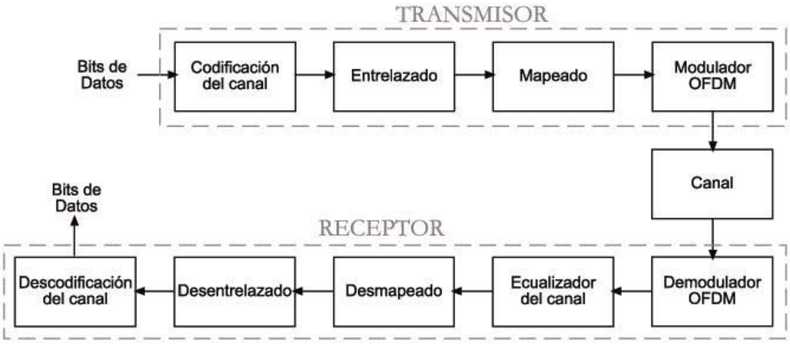


Diagrama de bloques transceptor

4. WPAN: Bluetooth, UWB, ZigBee and NFC.

Index

4. WPAN: Bluetooth, UWB, ZigBee and NFC.

- 4.1. Bluetooth
  - Introduction
  - Technology
  - Modulation characteristics
  - Versions
  - Uses and aplications
  - Types of devices
  - Interferences

4.1. Bluetooth

Introduction

- Global wireless communication standard in order to different devices interconnection.
- Voice and data transmission through a radio frequency link.
- SIG (Special Interest Group) was born with the objective of create a low cost and energy consumption communication in order to interconnect mobile phones with their accessories.

4.1. Bluetooth

Introduction

- The name comes from Danish and Norwegian King Harald Blåtand whose traduction to English would be Harold Bluetooth
- Bluetooth is based on MC link: short-range radio link
- 10 meters range, but it can reach up to 100 meters with repeaters

Lesson 7: wireless networks

4.1. Bluetooth

Technology

- Transmission speed up to 1 Mbps
- optimal range of 10 meters
- Frequency band: 2,4 - 2,48 GHz
- Radio frequency with frequency hoping spread spectrum and the possibility to transmit in Full Duplex up to 1600 hops/s.
- Frequency hoping in 79 frequencies with an interval of 1 MHz; this allows to give a secure and robust system

4.1. Bluetooth

Technology

- Output power in order to transmit to a 10 meters maximum distance is 0 dBm (1 mW), although long-term version transmits between 20 and 30 dBm (between 100 mW and 1 W).

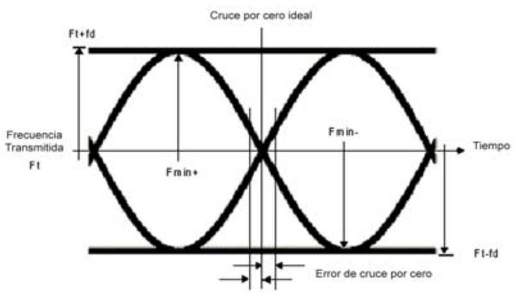
Clase de potencia	Potencia máxima de salida (Pmax)	Potencia de salida Nominal	Potencia mínima de salida	Control de potencia
1	100 mW (20 dBm)	N/A	1 mW (0 dBm)	Pmin>+4 dBm hasta Pmax opcional: Pmin hasta Pmax
2	2.5 mW (4 dBm)	1 mW (0 dBm)	0.25 mW (-6 DBm)	Opcional: Pmin hasta Pmax
3	1 mW (0 dBm)	N/A	N/A	Opcional: Pmin hasta Pmax

Clases de potencia

4.1. Bluetooth

Modulation characteristics

- GFSK modulation
- Modulation rate must be between 0.28 and 0.35.



Modulación de la transmisión actual

4.1. Bluetooth

Versions

- Bluetooth v.1.1
  - It has the problem that operates in the same frequency band than IEEE 802.11
- Bluetooth v.1.2
  - It resolves the interference problems between Wifi and BT in order to coexist in 2,4 GHz frequency band
  - It uses AFH (Adaptive Frequency Hopping) technique, that execute a more efficient and higher secure encryptation transmission.
  - it offers a quality voice with a lower environmental noise and a quick communication configuration with another bluetooth devices.
- Bluetooth v.2.0
  - It was created in order to be a separated specification, basically it incorporates EDR (Enhanced Data Rate) technique that allows to increase transmission speeds up to 3 Mbps more
  - It tries to resolve some v.1.2 problems
- Bluetooth v.3.0
  - It increases the speed up to 24 Mbps
- Bluetooth v.ULP
  - As known as Wibree, it reduces speed to 1 Mbps with an increase of consumption.

Lesson 7: wireless networks

4.1. Bluetooth

Uses and applications

- Wireless connections between mobile phones and handsfree units for cars.
- Wireless network in confined spaces where is not important a huge bandwidth.
- Wireless communication between PC and i\o devices. Mainly keyboard, printer and mouse
- Files transfer between devices via OBEX.
- Replacement of traditional cable communication between GPS equipment and medical equipment.
- Remote controls
- To send commercial messages between advertisers and bluetooth devices. A business could send commercials to mobiles with activate bluetooth when you are close to advertisers.

4.1. Bluetooth

Interferences

- Bluetooth works in a frequency band that is affected by several interferences
- Frequency hopping technique is used at a high speed and short size packets (1600 hops/second, for simple-slots). This allows to avoid most of interferences
- Voice are never transmit again, however, it is used a high solid codification diagram. This diagram, that is based on Continuously Variable Slope Delta (CVSD),it shapes to the audio wave and it is very resistant to bit errors. Those errors are considered as background noise, that is intensified if errors are increased.

Profiles

Bluetooth defines protocol stack with numerous protocols and parameters.
Not all protocols are required for all functions.
A Bluetooth profile specifies which specific parts of the Bluetooth stack used (with that particular options and parameters) to support a particular service.
The capabilities of a Bluetooth device are summarized through a classification of profiles.
Some profiles can be found in a mobile:

Advanced Audio Distribution Profile (A2DP): for transmitting a stereo stream into two channels to headphones.
Basic Imaging Profile (BIP): to send images.
Dial-up Networking Profile (DUN): Internet access using mobile phone (eg from a laptop).
File Transfer Profile (FTP): provides remote access to file systems mobile.
Hands-Free Profile (HFP): Handsfree use.

4. WPAN: Bluetooth, UWB, ZigBee and NFC.

- 4.2. Ultra WideBand
  - Introduction
  - Theorical issues
  - Transmission mode
  - Aplications
    - Wireless alternative
    - technology challenges
    - legal issues
  - Conclusions

4.2. Ultra WideBand

Introduction (1)

UWB → Transmission technique where information is transported by impulses of very high speed.

- ✓ Bandwidth ~ GHz,
- ✓ Low power transmission (it allows coexistence with another users)
- ✓ It comes from Radar and military aplications.
- ✓ Uses: communication, objects detection and positioning.
- ✓ Dozens of Mbps of transmission
- ✓ Hundred of simultaneosusly users
- ✓ Interference resistance
- ✓ Hugh channel capacity with low consumption
- ✓ Wireless communication option.

4.2. Ultra WideBand

Introduction (2)

- UWB is been standardizing in three different IEEE standards. IEEE 802.15.3a (rejected) included two offers for UWB: OFDM offer, of Multiband OFDM Alliance and Direct Sequence (DS) offer.
- In IEEE 802.15.4a, DS offer was approved for low information rates. Moreover, it is been debated the addition of UWB as a physical layer for Bluetooth, in IEEE 802.15.1.
- Nowadays it has been approved ECMA-368 standard, that coincides with ISO/IEC 26907 and it uses a OFDM multiband (MB-OFDM).

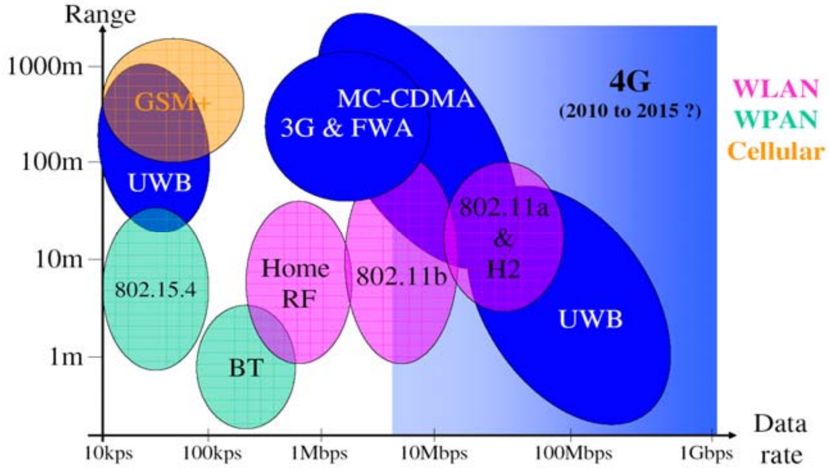
Lesson 7: wireless networks

4.2. Ultra WideBand

Theorical issues (1)

- UWB definition → sysytems that have a transmission bandwidth occupied
  - + 25% of f_c
  - + 1,5 GHz
  - ✓ BW bigger than in narrowband.
- System without carrier → *carrierless*
- Signals in baseband → it is composed by short period monocycles
  - ✓ It is face directly the antenna.
  - ✓ Period < 1ns
  - ✓ Uplink and downlink periods with very incline slope
  - ✓ Frequency response with BW from 650 MHz to 5 GHZ.

UWB systems scenario



BT-Bluetooth; 802.11~WI-FI; WLAN-Wireless Local Area Network; WPAN-Wireless Personal Area Network; MC-CDMA-MultiCarrier-Code Division Multiple Access; FWA-Fixed Wireless Access (o WLL-Wireless Local Loop)

Definitions and concepts.

UWB is used in different fields:

- ***impulse radio*** (as, for example, impulse radar)

- ***carrierless or carrier-free*** systems (without carrier)

- baseband signal transmission with GHz bandwidths, very short duration pulses in the time domain ...

Actually, the UWB term did not begin to applied to systems with these features until 1989 by the Department of Defense (DoD) of the United States.

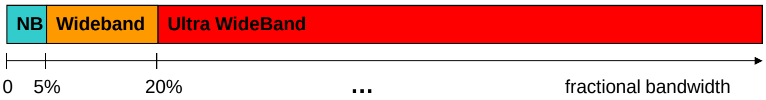
Today, this term, but may still have the above connotations, is defined in terms of bandwidth, and is not defined in terms of modulation, or no carrier, or duration of the pulses.

A UWB signal must accommplised one of the two conditions A) or B):

A) fractional bandwidth B / f between points to 10 dB is greater or equal to 20%

$$\frac{B}{f_o} = 2\frac{f_U - f_L}{f_U + f_L} \times 100 > 20\%$$

fU, fL: higher frequency, lower than the prower spectral density is 10 dB below the maximum



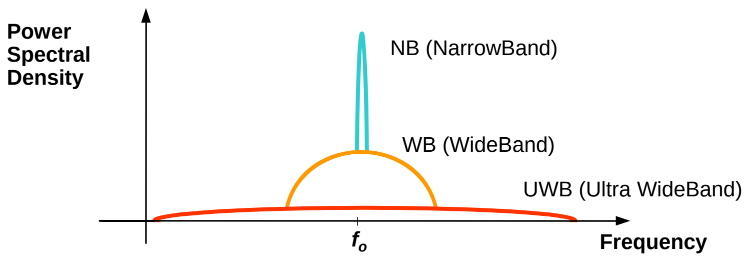
- B) Absolute bandwidth B is greater or equal to 500 MHz, regardless of the center frequency:

$$B = f_U - f_L > 500 \text{ MHz}$$

There are other alternative definitions, for example, define UWB if the relative bandwidth is greater than 25% or greater than 1.5 GHz

Lesson 7: wireless networks

UWB signals:



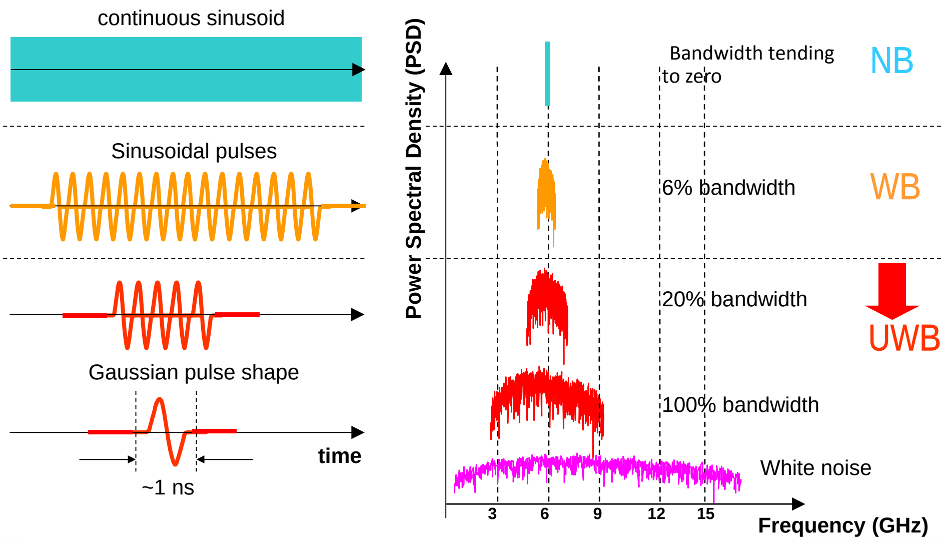
Approximate bandwidths on some systems:

	GSM	UMTS	801.11a (WI-FI)	GPS
B (aprox)	Channels between 200 KHz to 25 MHz	3.8 MHz	16.6 MHz	20 MHz
f_0 (approx.)	900,1800 MHz	1950,2150 MHz	2400 MHz	1600 MHz
B(%)=B/f_0 × 100	0.02% - 3%	0.2%	0.7%	1.3%

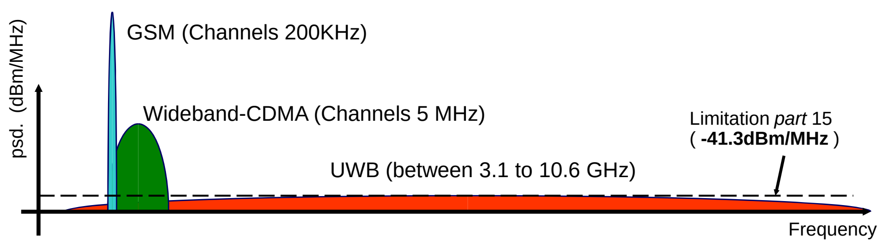
Advanced Technology in Radiocommunications

UNIVERSITAS Miguel Hernández

NB/WB/UWB signals:



UWB spectrum:



- UWB is a form of extremely wide range spectrum, both absolute and relative, where the RF energy is distributed about GHz spectrum

- Wider than any narrowband system by orders of magnitude

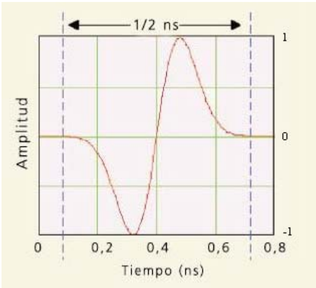
- The UWB signal power that are detecting by narrowband systems are only a fraction of the total

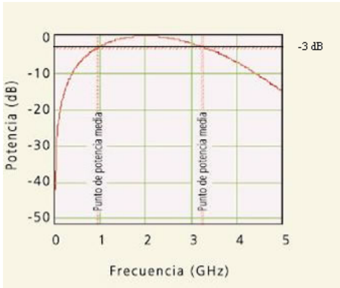
- The UWB signals are seen by other systems as noise

We will have to calculate the mutual interference between UWB and NB systems sharing spectrum areas

4.2. Ultra WideBand

Theorical issues (2)





Frequency and temporary response of a monocycle

4.2. Ultra WideBand

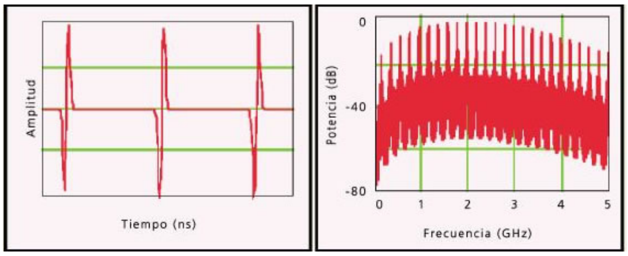
Theorical issues (3)

- Huge BW → Posibility of big channel capacities with low SNR accordint to Shannon theorem.
  - ✓ Capacity(bps)= Bandwidth(Hz)x$\log_2$(1+SNR)
- Power transmission reduction → UWB is a good alternative for low consumption communications.

4.2. Ultra WideBand

Transmission mode (1)

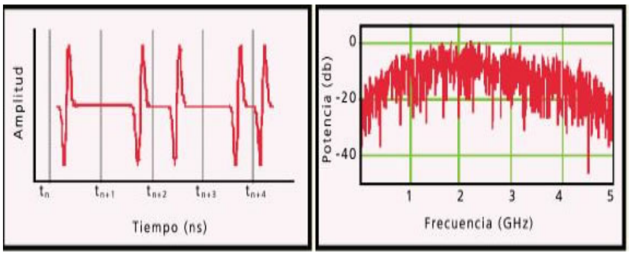
- Transmission is made according to a basic sequence of monocycles →



Frequency and temporary response of a monocycle without PN code

4.2. Ultra WideBand

Transmission mode (2)

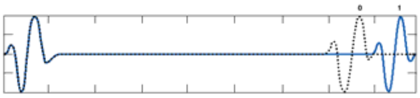


Frequency and temporary response of a monocycle with PN code.

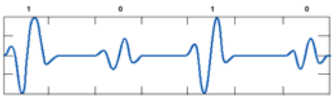
Transmission mode (3)

Modulations implemented to transmit information

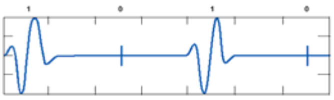
- ✓ PPM (Pulse Position Modulation).



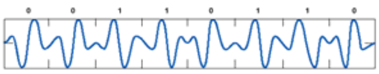
- ✓ PAM (Pulse Amplitude Modulation)



- ✓ OOK (On-Off keying).



- ✓ BPSK (Binary phase-shift keying).



4.2. Ultra WideBand

Transmission mode (3)

- ➢ Modulations are implemented in order to transmit the information
  - ✓ BPSK (Binary phase-shift keying).
  - ✓ PAM (Pulse Amplitude Modulation).
  - ✓ OOK (On-Off keying).
  - ✓ PPM (Pulse Position Modulation).

4.2. Ultra WideBand

Transmission mode(4)

- Most popular modulation → PPM (Pulse-position modulation).
  - ✓ Send of N_s pulses by baud
  - ✓ PPM modulation carrying out
  - ✓ Monocycles position are displaced an amount that depends on the information.
- Mathematical expression is:

$$S_{tr}^{(k)}(t^{(k)}) = \sum_{j=-\infty}^{\infty} w_{tr}(t^{(k)} - jT_f - c_j^{(k)}T_c - \mu d_{|j/N_s|}^{(k)}$$

4.2. Ultra WideBand

Transmission mode (5)

- Speed transmission →

$$SR = \frac{1}{N_s T_f} bauds / Seg$$

- Steps for reception →
  - ✓ Generation in reception of a correlated mask with the input signal
  - ✓ Knowing PN sequence, correlator will generate an output signal that depends on the transmitted information, where it will be integrated the information of Ns transmitted pulses.
  - ✓ Integrator output will be analyzed by a comparator that will characterize the information of the transmitted information.

4.2. Ultra WideBand

Applications (1)

- Wireless communication disadvantages:
  - Multipath propagation:
  - ✓ Transmitted signal reflections
  - ✓ If there are destructive interference the channel will be cancelled.
- Very damaging effect inside the buildings
- SOLUTION → UWB
  - ✓ It minimizes the effect because of temporary domain signal
  - ✓ Reflection will cause a delayed pulse
  - ✓ So, UWB is an alternative for indoor communications.

4.2. Ultra WideBand

Applications (2)

- Another advantage of UWB → better penetrability in materials, because of low central frequency
- UWB system applications according to FCC (Federal Communication Commission) in the 15 report →
  - ✓ Systems of images
    - – Earth penetration radars
  - ✓ Sensors and images inside the walls
  - ✓ Images through the walls
  - ✓ Survival systems
  - ✓ Medical applications
    - – Radar systems for transports
    - – Communications and measure systems.

4.2. Ultra WideBand

Applications (3)

Wireless alternative

- In order to compare different wireless technologies we use *spatial capacity* term, given by the next expression :

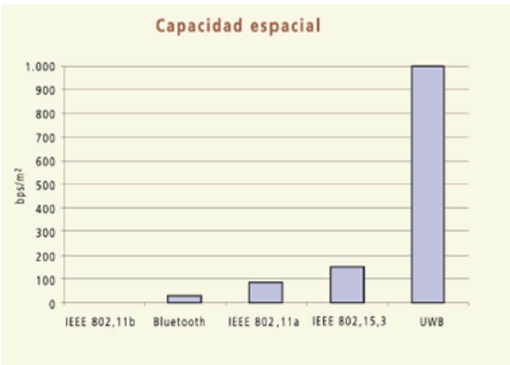
$$C = \frac{N \times bps}{\pi \times d^2}$$

- ✓ With this expression we can deduce that UWB systems has a great potential in order to be used in wireless communications that require a short-range and a high channel capacity
- ✓ It has a capacity of transmit 100 Mbps with 200 mW in a range of 10 meters → ideal technology in order to wireless LAN networks communications.

4.2. Ultra WideBand

Applications (4)

Wireless alternative



Spatial capacity graphic where it is compared several wireless technologies

4.2. Ultra WideBand

Applications (5)

Technology challenges

- this type of technology requires a serie of features, because of the great bandwidth that it has →
  - ✓ Need of a good impedance matching between the different stages that makes up the transmission chain.
  - ✓ In equispaced time pulse transmissions, it is necessary both receiver and emitter are correctly synchronized.
  - ✓ In order to increase channel capacity or the number of users you have to reduce the pulse wide → commitment between pulse wide and capacity
  - ✓ Being pulse wide < 1ns you have to use SiGe in pulse generation circuits, that increases considerably the cost.

4.2. Ultra WideBand

Applications (6)

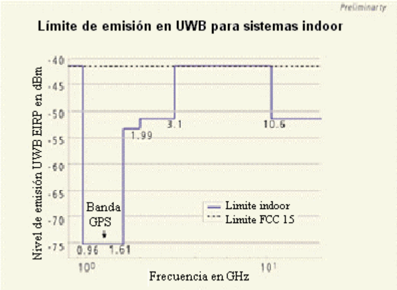
Legal issues

- UWB systems do not focus the energy in a specific frequency band→ they spread the energy in a wide frequency band.
  - ✓ It can interfere in actual systems.
- Regulations must assure that UWB systems has no any interference in implemented radio systems (BlueTooth, 802.11a, 802.11b, HiperLan/2).
- In order to avoid this, FCC launched an emission pattern draft, where power that can transmit is less than FCC 15 levels that regulate the rest of electric equipment. Although, according to FCC, regulation can be strict, it can be modified in future.
- Europe → without any regulation, it will be similar to USA one , CEPT S24 work station and ETSI TG 31a.

4.2. Ultra WideBand

Applications (7)

Legal issues



Emission pattern of FCC for UWB indoor communications

Receivers design

- No carrier, it means that are simplified and cheaper circuit transmitter and receiver (no need to generate a replica of the carrier at the receiver and no problems of coherence frequency / phase).
- No RF stages (smaller size, power consumption and cost).
- AD converters require high sampling frequency (several GHz, ns pulses).
- The AD converter see the whole band UWB signal (narrowband interference can affect the system)
- Instead of using the entire spectrum with a single type of pulses, the spectrum available (pulsed multiband UWB) is channeled

Multiband proposals de UWB

Multiband carrier-based UWB | **Multiband pulsed UWB**

UWB technique	*A) OFDM*	*B) TDMA/FDMA Pulsos*	*C) DSSS/CDMA*
Bands	3 to 13 (in 5 groups)	3 to 13	2
Bandwidths	528 MHz	550 MHz	1.368 GHz, 2.736 GHz
Frequency ranges	3.168 GHz – 4.752 GHz 4.752 – 10.296	3.325 GHz – 4.975 GHz, 4.975 GHz – 10.475 GHz	3.1 GHz – 5.15 GHz 5.825 GHz – 10.6 GHz
Modulation schemes	OFDM, QPSK (based in carrier)	M-ary Bi-Orthogonal Keying (M-BOK), Quaternary-Phase (Pulso)	Bi-phase, Quaternary-phase, M-BOK (Pulso)
Errors Correction	Convolutional code	Convolutional code Reed-Solomon code	Convolutional code Reed-Solomon code
Code ratest	11/32 at 110 Mbps, 5/8 at 200 Mbps, ¾ at 480 Mbps	6/32 at 110 Mbps, 5/16 ta 200 Mbps, ¾ at 480 Mbps	½ at 110 Mbps, RS(255,223) at 200 Mbps, RS(255,223) at 480 Mbps
Link Margin	5.3/6 dB at 10 m / 110 Mbps, 10.7 dB ta 4 m / 200 Mbps, 6.2 dB at 4 m / 480 Mbps	6.3 dB at 10 m / 108 Mbps, 8.0 dB at 4 m / 288 Mbps, 4.0 dB at 4 m / 577 Mbps	6.1 dB at 10 m / 110 Mbps, 11.1 dB at 4 m / 200 Mbps, 6.1 dB at 4 m / 600 Mbps
Symbol period	312.5 ns OFDM symbol	3 ns	23 or 17.5 ns (low band), 11.7 or 8.9 ns (high band)
mitigation Multipath method	1-tap (60.6 ns delay spread)	Frequency interleaving MBOK chips; time frequency code	Equalizer with feedback Decision

4.2. Ultra WideBand

<u>Conclusions</u>

- UWB system → alternative in order to indoor communication.
  - ✓ Great channel capacity and low consumption.
  - ✓ It is still not technologically available in low cost.
  - ✓ Spectrum re-using
- UWB constitution has a legal challenge.
  - ✓ It is different to actual transmission systems
  - ✓ It is necessary to establish regulations in order to avoid interferences between UWB communications and the rest of actual systems
- Possible UWB applications in electric devices (TV, DVD, fridge, HiFi)Paso de imágenes de la cámara digital a la TV a al PC.
  - ✓ Internet connection from a near link
  - ✓ DVD film view in two different TV with digital quality
  - ✓ Buy from fridge .

4. WPAN: Bluetooth, UWB, ZigBee and NFC.

- 4.3. ZigBee
  - Introduction
  - History
  - General characteristics
  - Speeds and Frequencies
  - Topology models
  - Applications

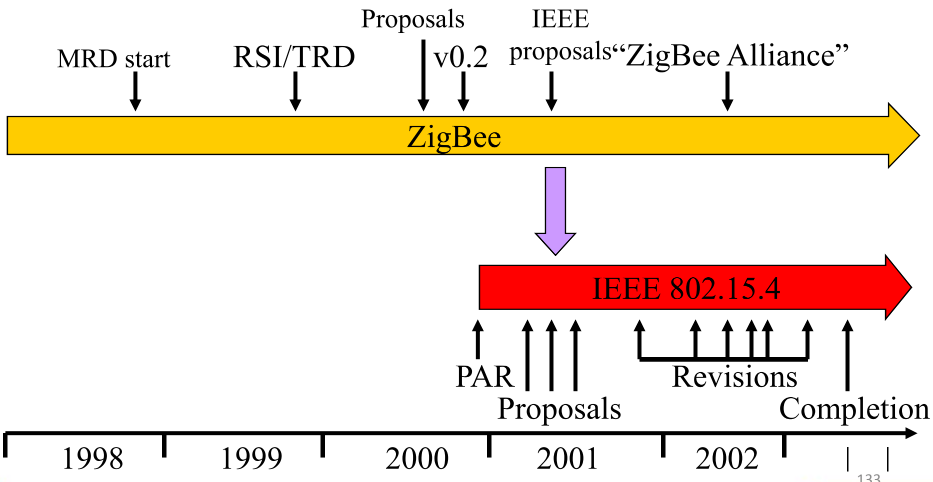
4.3. ZigBee

Introduction

- Standard IEEE 802.15.4, as known as Zigbee, it was developed in order to the interconnection of devices:
  - low speed
  - low power
  - low complexity (easy integration)
  - short range
  - not many frequencies
  - wireless use in a WPAN

4.3. ZigBee

History



4.3. ZigBee

General characteristics

- Normally, it works in POS (*Personal Operating Space*) in a range of 10 meters, but it can work up to 75 meters.
- ISM bands of 868 MHz, 915 MHz or 2,4 GHz, the two first frequencies are only available in USA and Europe.
- Last version of this standard includes frequencies in 169, 433, 450, 470, 780, 863, 896, 901, 915, 917, 920, 928, 950, 1427, 2400, 6489.6, 6988.8 and 7987.2 MHz
- Original version has 27 channels, with 16 of them in 2,4 GHz band, most efficient band referred to bandwidth use. Channels of 2 MHz with a distance between them of 5 MHz.
- For security of the information, it works with AES (Advanced Encryption Standard).
- To get a minimum consumption of the network nodes (it can take more than 5 years)

4.3. ZigBee

Versions

- ZigBee v.1.0
  – It was approved in December of 2004 and it is available for development members group. It is also knwon as ZigBee 2004.
- ZigBee v.2.0
  – It is the second and actual version, it was approved in 2006 and it was called ZigBee 2006, it replace the MSG/KVP structure with a cluster library, making the previous version is obsolete.
- ZigBee 2007
  – It also includes some new application shapes, such as automatic read, commercial building automation, and house automation based on cluster library use, in fact ,it is a stack shape that defines some characteristics about it.
  – Network level of ZigBee 2007 is not compatible with ZigBee 2004-2006 one, although a RFD node can connect to a 2007 network and vice versa. You cannot combine previous version routers with a 2007 coordinator.

Versions

- ZigBee 2009
- Includes recommendation IEEE 802.15.4c-2009 and IEEE802.15.4d-2009. Paging Channel 5 and 6. Bands of 780 and 950 MHz
- ZigBee 2012
- Includes recommendations IEEE 802.15.4e 2012, IEEE 802.15.4f 2012 and IEEE 802.15.4g-2012. Paging Channel 7, 8, 9 and 10. Bands of 169, 433, 450, 470, 780, 863, 896, 901, 915, 917, 920, 928, 950, 1427 and 2400 MHz
- You are referring to the MAC sublayer, active RFID physical layer or the physical layer specifications for smart meter networks with low data rate.

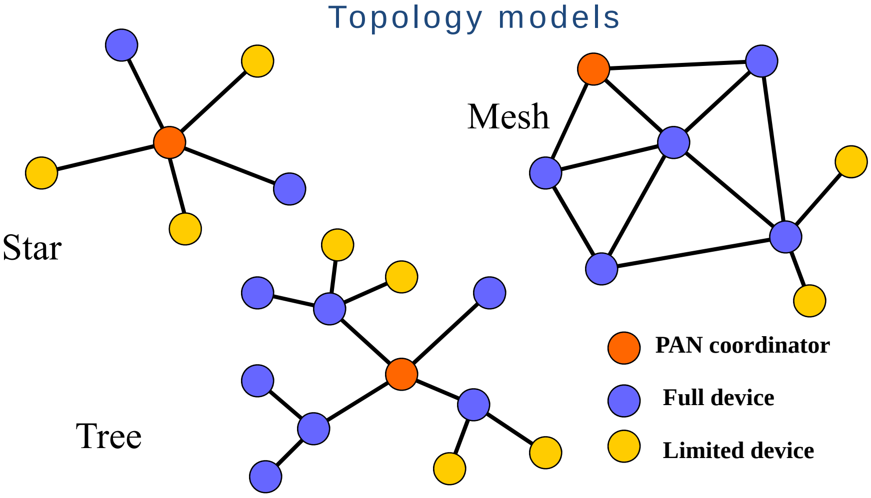
4.3. ZigBee

Speeds and Frequencies

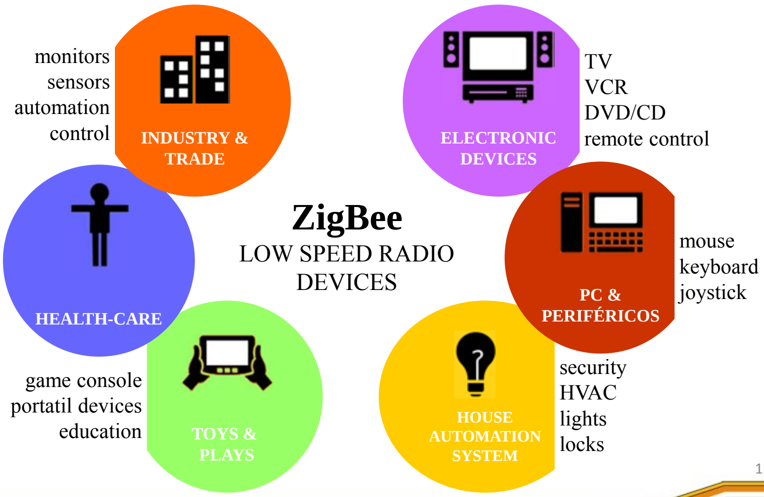
	BAND	COVERAGE	SPEED	CHANNEL(S)
2.4 GHz	ISM	All around the world	250 kbps	11-26
868 MHz		Europe	20 kbps	0
915 MHz	ISM	America	40 kbps	1-10

4.3. ZigBee

Topology models



4.3. ZigBee
Applications



4. WPAN: Bluetooth, UWB, ZigBee and NFC.

- 4.4. NFC
  - Introduction
  - General characteristics
  - Modulation
  - Applications

4.4. NFC

Introduction

- Near Field Communication or NFC is a wireless communication technology with short-range and low frequencies that allows data exchange between devices in a range less than 10 cm. It is a extension of ISO 14443 (RFID) standard.

4.4. NFC

General characteristics

- It communicates through induction in a magnetic field.
- It works in 13,56 MHz band.
- Speeds between 106, 212, 424 or 848 Kbits/s.
- All devices of the NFCIP-1 standard can work in two different modes:
  - Active: both of them generate their own electromagnetic field.
  - Passive: only one device can generate the electromagnetic field and the other take advantage of the load modulation in order to transfer the data. The master of the communication is in charge of generating the electromagnetic field.

4.4. NFC

Modulation

- ASK (Amplitude-Shift Keying) and two codes, according to mode:
  - Pasive: Manchester codification with 10% modulation rate.
  - Active: Miller codification with 100% modulation rate (just at 106 Kbps, the rest, Manchester).

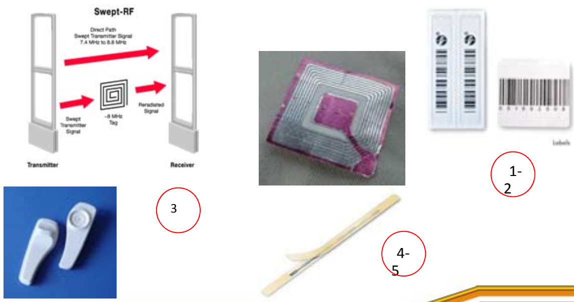
RFID

- Acronym for Radio Frequency Identification Systems that use radio frequency to identify people / objects

RFID = Identification + low cost + Passive

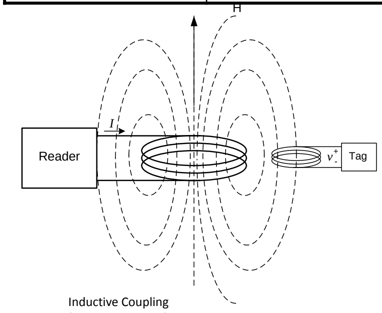
- EAS: Electronic Article Surveillance (no son RFID)

1. Radiofrequency
2. Frequency divisor
3. Microwave
4. Electromagnetic
5. Magnetoacustics

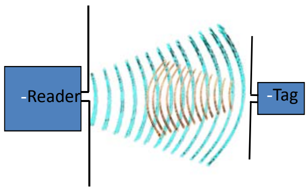


Physical principles of operation

	LF	HF	UHF	MICROWAVE
Frequency	135kHz	13.56 MHz	860-930 MHz	2.45 GHz
$\lambda/(2\pi)$	353 m	3.5 m	5 cm	2 cm
Coupling	Inductive coupling		Backscattering	



Inductive Coupling
(Load modulation)



Backscattering
(Reflection cross-section)

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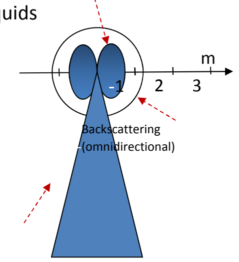
LF y HF (acoplamiento inductivo):

Much more efficient transmission of power.
It is not affected by multipath propagation, metals and liquids



UHF y Microwave (backscattering):

Higher operating ranges
Higher speeds
Potentially cheaper (smaller antennas).

Backscattering
(directional)

LF and HF (inductive coupling):

ANIMAL IDENTIFICATION
VEHICLE IMMOBILISER
ACCESS CONTROL

-LF (ISO 14223)
-Loop (300-500 loops)

SMART CARDS
ACCESS CONTROL
CONTROL EQUIPMENT

-HF (ISO 14443, Mifare) compatible with NFC
-Loop (3-8 loops, printed circuit)

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Usos:

UHF y Microwave (backscattering):

ELECTRONIC TOLL
ENCLOSURES LABELING
CONTROL EQUIPMENT

-UHF (EPCC1G2, WISP)

-EPCC1G2

-Metall

ELECTRONIC TOLL
STORAGE CONTROL
IDENTIFICATION OF CONTAINERS

-Microwave

2.45 GHz. Most are active

NFC

Características generales

- Se comunica mediante inducción en un campo magnético.
- Trabaja en la banda de los 13,56 MHz .
- Velocidades entre 106, 212, 424 o 848 Kbit/s .
- Todos los dispositivos del estándar NFCIP-1 pueden trabajar en dos modos diferentes:
  - Activo: ambos dispositivos generan su propio campo electromagnético
  - Pasivo: sólo un dispositivo genera el campo electromagnético y el otro se aprovecha de la modulación de la carga para poder transferir los datos. El iniciador de la comunicación es el encargado de generar el campo electromagnético.

4.4. NFC

Applications

- Telefónica, La Caixa and Visa, take part in a pilot project with mobiles with NFC technology.
- BMW studies to use this integrated technology in cars in order to buy things online.
- Samsung incorporates NFC in their mobiles, like Wave 578 one.
- Android offers a NFC API that allows the read and write access in order to NFC labels can use it.

5. Comparative between different technologies.

Index

5.1. Channels of every standard (1)

- IEEE 802.11 channels

Número de canal	Frecuencia GHz	Norte América	Europa	España	China	Japón - MKK
1	2.412	X	X	X	X	X
2	2.417	X	X	X	X	X
3	2.422	X	X	X	X	X
4	2.427	X	X	X	X	X
5	2.432	X	X	X	X	X
6	2.437	X	X	X	X	X
7	2.442	X	X	X	X	X
8	2.447	X	X	X	X	X
9	2.452	X	X	X	X	X
10	2.457	X	X	X	X	X
11	2.462	X	X	X	X	X
12	2.467		X	X		X
13	2.472		X	X		X
14	2.483					X

Canales de DSSS para varias partes del Mundo

5.1. Channels of every standard (2)

- IEEE 802.11a channels

Dominio Regulatorio	Banda (GHz)	Números de canal de operación	Frecuencias centrales de canal (MHz)
Estados Unidos	Banda inferior U-NII (5.15-5.25)	36 40 44 48	5180 5200 5220 5240
Estados Unidos	Banda media U-NII (5.25-5.35)	52 56 60 64	5260 5280 5300 5320
Estados Unidos	Banda superior U-NII (5.725-5.825)	149 153 157 161	5745 5765 5785 5805

Números de canal de operación válidos por dominio regulatorio y banda

5.1. Channels of every standard (3)

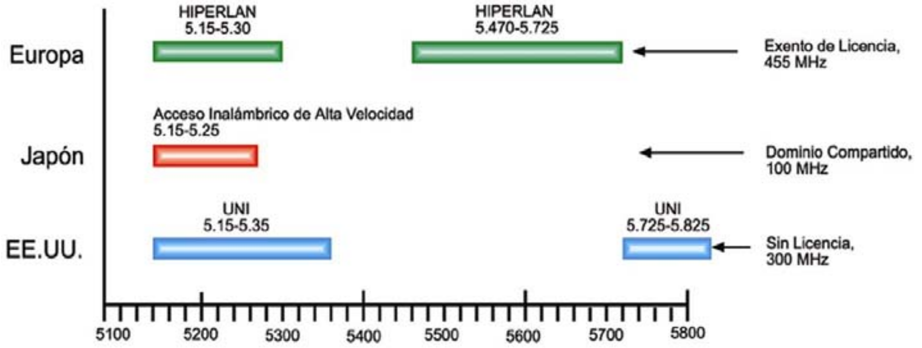
- IEEE 802.11b channels

		Dominio Regulador					
CHNL_ID	Frecuencia (MHz)	X '10' FCC	X '20' IC	X '30' ETSI	X '31' España	China	Japón
1	2.412	X	X	X	X	X	X
2	2.417	X	X	X	X	X	X
3	2.422	X	X	X	X	X	X
4	2.427	X	X	X	X	X	X
5	2.432	X	X	X	X	X	X
6	2.437	X	X	X	X	X	X
7	2.442	X	X	X	X	X	X
8	2.447	X	X	X	X	X	X
9	2.452	X	X	X	X	X	X
10	2.457	X	X	X	X	X	X
11	2.462	X	X	X	X	X	X
12	2.467			X	X		X
13	2.472			X	X		X
14	2.483						X

Plan de canales de frecuencias de la capa física para altas velocidades

5.1. Channels of every standard (4)

- HIPERLAN/2 channels



Distribución del espectro actual

5.1. Channels of every standard (5)

- Bluetooth channels

Geografía	Rango regulador	Canales RF
EEUU, Europa y otros países	2.400-2.4835 GHz	f=2402+k MHz, k=0,…,78

Bandas de frecuencias operativas

5.2. Modulation of every standard (1)

- IEEE 802.11 modulation

Velocidad de datos (Mbps)	Tasa	Modulación
1	1/2	DBPSK, GFSK
2	1/2	DQPSK, GFSK

5.2. Modulation of every standard (2)

- IEEE 802.11a modulation

Velocidad de Datos (Mbits/s)	Modulación	Tasa de codificación (R)	Bits codificados por subportadora (N_{BPSC})	Bits codificados por símbolo OFDM (N_{CBPS})	Bits de Datos por símbolo OFDM (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Parámetros de Velocidad dependiente

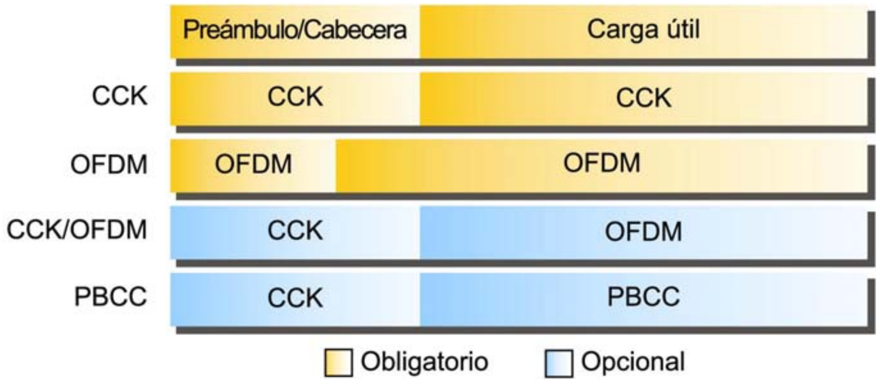
5.2. Modulation of every standard (3)

- IEEE 802.11b modulation

Velocidad de datos (Mbps)	Modulación Obligatoria	Modulación Opcional
1	BPSK	
2	QPSK	
5.5	CCK	PBCC
11	CCK	PBCC

5.2. Modulation of every standard (4)

- IEEE 802.11g modulation



5.2. Modulation of every standard (5)

- IEEE 802.11g modulation

Velocidad de datos (Mbps)	Modulación Obligatoria	Modulación Opcional
1	Barker	
2	Barker	
5.5	CCK	PBCC
6	OFDM	CCK-OFDM
9		OFDM, CCK-OFDM
11	CCK	PBCC
12	OFDM	CCK-OFDM
18		OFDM, CCK-OFDM
22		PBCC
24	OFDM	CCK-OFDM
33		PBCC
36		OFDM, CCK-OFDM
48		OFDM, CCK-OFDM
54		OFDM, CCK-OFDM

5.2. Modulation of every standard (6)

- HIPERLAN/2 modulation

Modo	Modulación	Tasa de Código	Tasa de bit de la Capa Física	Bytes/ simb. OFDM	Bits codificados por subportadora N_{BPSC}	Bits codificados por simb. OFDM N_{CBPS}	Bits de datos por simb. OFDM N_{DBPS}
1	BPSK	1/2	6 Mbps	3.0	1	48	24
2	BPSK	3/4	9 Mbps	4.5	1	48	36
3	QPSK	1/2	12 Mbps	6.0	2	96	48
4	QPSK	3/4	18 Mbps	9.0	2	96	72
5	16QAM	9/16	27 Mbps	13.5	4	192	108
6	16QAM	3/4	36 Mbps	18.0	4	192	144
7	64QAM	3/4	54 Mbps	27.0	6	288	216

Modos de la Capa Física definidos por HIPERLAN/2

5.3. Comparative: different wireless technologies

Standard	Spectrum (GHz)	Max. Transmission rate(Mbps)	Connection	Point to multipoint communication	Physical networks support
802.11	2,4	2	No connection oriented	Yes	Ethernet
802.11a	5	54	No connection oriented	Yes	Ethernet
802.11b	2,4	11	No connection oriented	Yes	Ethernet
802.11g	2,4	54	No connection oriented	Yes	Ethernet
802.16	11 -- 66	134		Yes	
802.16a	2 -- 11	54		Yes	
802.16d	2 -- 11	134		Yes	
802.16e	2 -- 6	54		Yes	
HIPERLAN/2	5	54	No connection oriented	Yes	Ethernet, IP, ATM, UMTS, FireWire, PPP
Bluetooth	2,4	2	No connection oriented	Yes	Ethernet
ZigBee (802.15.4)	2,4	250 kbps			
UWB	3,1 - 10,6	500	No connection oriented	Yes	

5.3. Comparative: different wireless technologies

Standard	Frequency selection	Channels (GHz)	Power (mW)	Range (m)		Modulation
				indoor	Free space	
802.11	FHSS, DSSS, infrared	2,412 - 2,472 (Spain)	100	150	300	DBPSK, DQPSK
802.11a	Unique carrier (OFDM)	5,15 - 5,25	40	12 -- 50	30 -- 150	BPSK, QPSK, 16-QAM, 64-QAM
		5,25 - 5,35	200			
		5,725 - 5,825	800			
802.11b	DSSS	2,412 - 2,472 (Spain)	100	30 -- 90	150 -- 300	CCK, DBPSK, DQPSK
802.11g	Unique carrier (OFDM)	2,412 - 2,472 (Spain)	100	30 -- 90	150 -- 300	CCK, OFDM
HIPERLAN/2	Unique carrier with dinamic frequency selection (OFDM)	5,15 - 5,30	200 (indoor)	30 -- 150	300	BPSK, QPSK, 16-QAM, 64-QAM
		5,470 - 5,725	1 W (free space)			

5.3. Comparative: different wireless technologies

Standard	Frequency selection	Channels (GHz)	Power (mW)	Range (m)		Modulation
				indoor	Free space	
802.16		11 -- 66	200	---	5.000	QPSK, 16-QAM, 64-QAM
802.16a		2 -- 11	200	---	50.000	OFDM with 256 subcarriers QPSK, 16QAM, 64QAM
802.16d		2 -- 11	200	---	50.000	OFDM with 256 subcarriers QPSK, 16QAM, 64QAM
802.16e		3.5, 5.8 (Europe)	200	---	5.000	OFDM with 256 subcarriers QPSK, 16QAM, 64QAM

5.3. Comparative: different wireless technologies

Standard	Frequency selection	Channels (GHz)	Power (mW)		Range (m)		Modulation
					indoor	Free space	
Bluetooth	FHSS	2,400 - 2,483	Class 1	100	10	100	GFSK, DBPSK, DQPSK
			Class 2	2,5			
			Class 3	1			
NFC		0,001356			0.04-0.2	0.04-0.2	Manchester, ASK
ZigBee (802.15.4)	DSSS	2,400 - 2,483	100		---	70	DSSS
UWB		3,1 - 10,6	1		---	10	BPSK, PAM, OOK, PPM

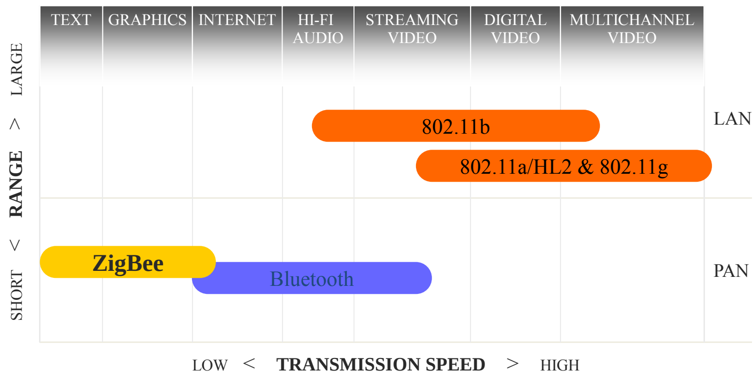
Lesson 7: wireless networks

5.3. Comparative: different wireless technologies

- ZigBee vs Bluetooth

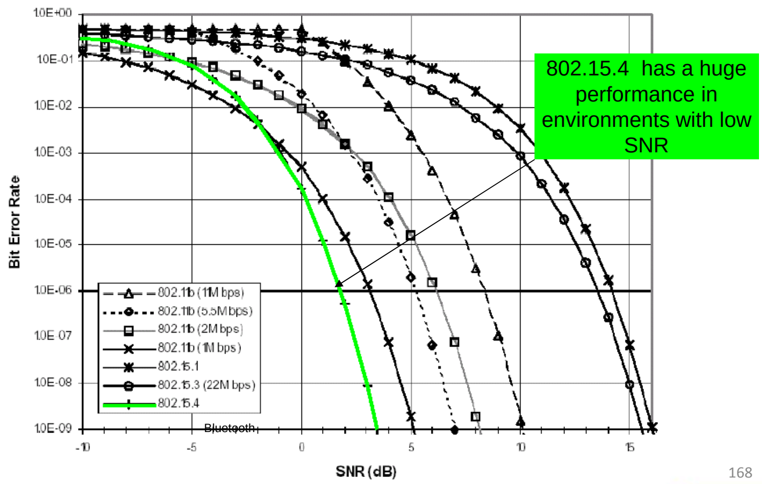
	Bluetooth	Zigbee
Max. Network nodes number	8	65535
Modulation	FHSS	DSSS
Stack protocol size	250 kbyte	28 kbyte
Electric comsumption	40 mA (tx) 0.2 mA (stand by)	30 mA (tx) 3 µA (stand by)
Battery	No rechargeable	rechargeable
Maximum speed transmission	1 Mbps	250 kbps
Range	From 1 to 100 metros, in function of the type of class	Up to 70 meters
Network citical time	3 seconds	30 miliseconds

5.3. Comparative: different wireless technologies



5.3. Comparative: different wireless technologies

- BER comparative for 802.11b, 802.15.4 and Bluetooth



5.3. Comparative: different wireless technologies