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- Concept of ISM frequency band
- Free-space loss and frequency dependency
- Comparison between different wireless technologies (PHY and MAC layers)
- MAC and IP addressing issues

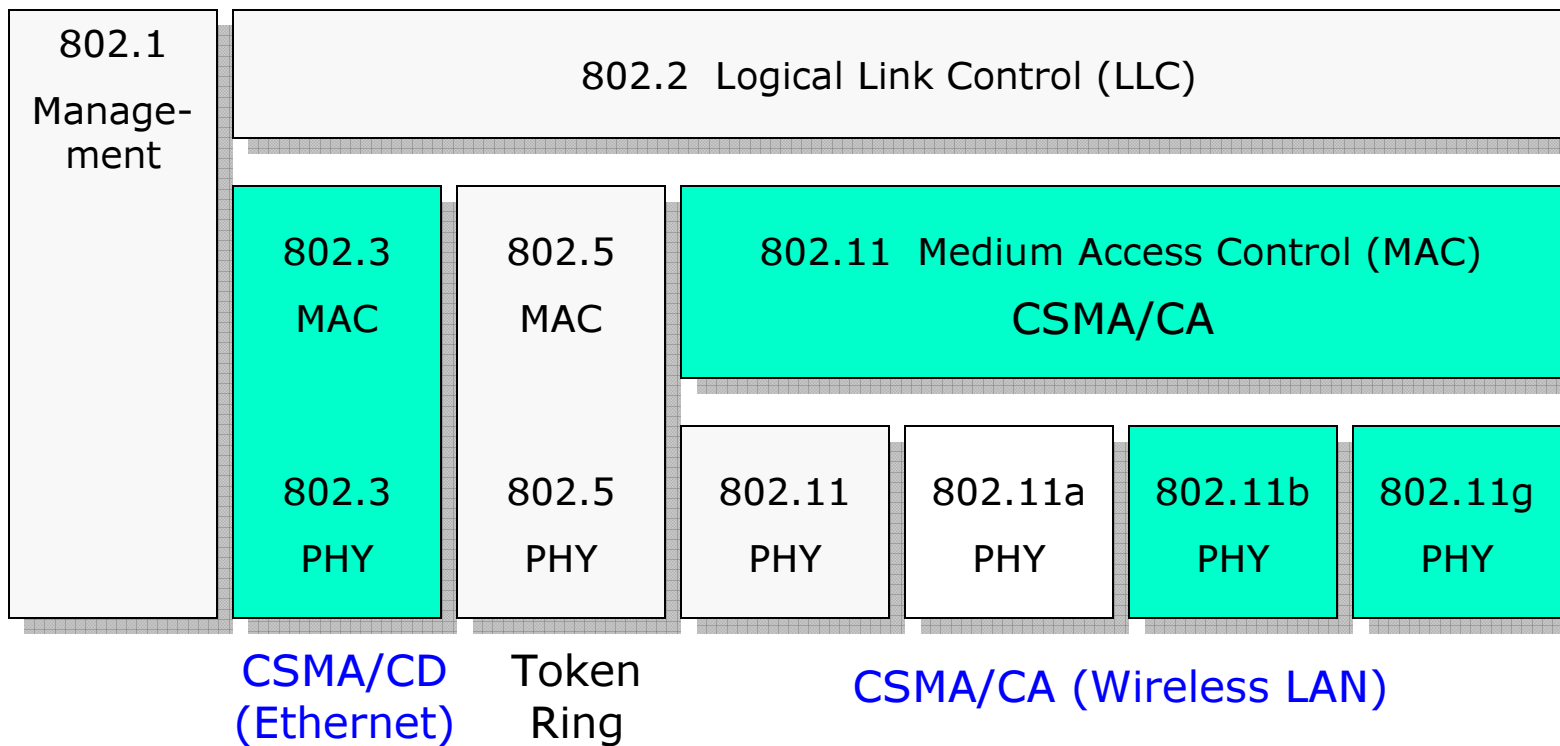


IEEE 802 wireless network technology options

<i>Network definition</i>	<i>IEEE standard</i>	<i>Known as</i>
Wireless personal area network (WPAN)	IEEE 802.15.1	Bluetooth
Low-rate WPAN (LR-WPAN)	IEEE 802.15.4	ZigBee
Wireless local area network (WLAN)	IEEE 802.11	WiFi
Wireless metropolitan area network (WMAN)	IEEE 802.16	WiMAX

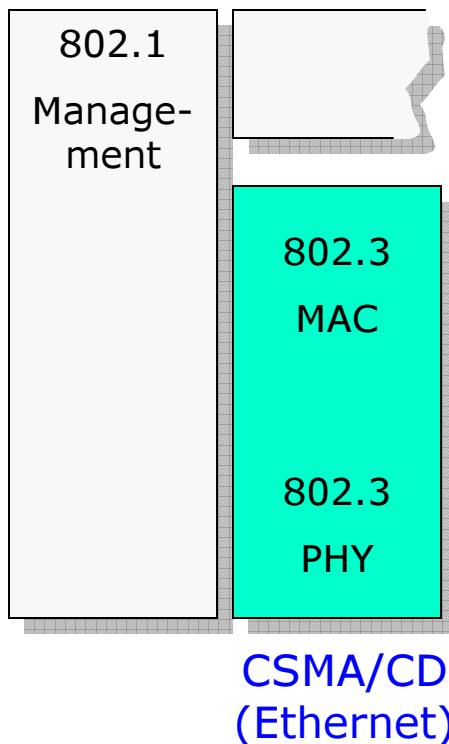


IEEE 802 standardisation framework





CSMA/CD Ethernet



Widely used **wired** LAN technology

CSMA/CD = Carrier Sense Multiple Access with **Collision Detection**

LAN stations compete for accessing the shared medium (wired network). If a collision is detected, transmitting stations stop their transmissions and wait a random time before starting transmission again.



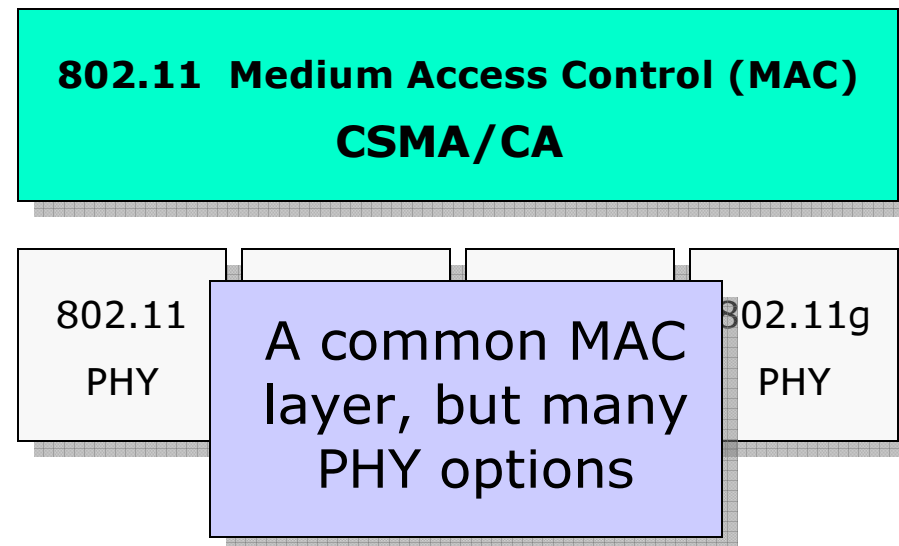
CSMA/CA Wireless LAN

CSMA/CA = Carrier Sense Multiple Access with **Collision Avoidance**

Unlike wired LAN stations, WLAN stations cannot detect collisions

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avoid collisions (use "backoff procedure" as described later)





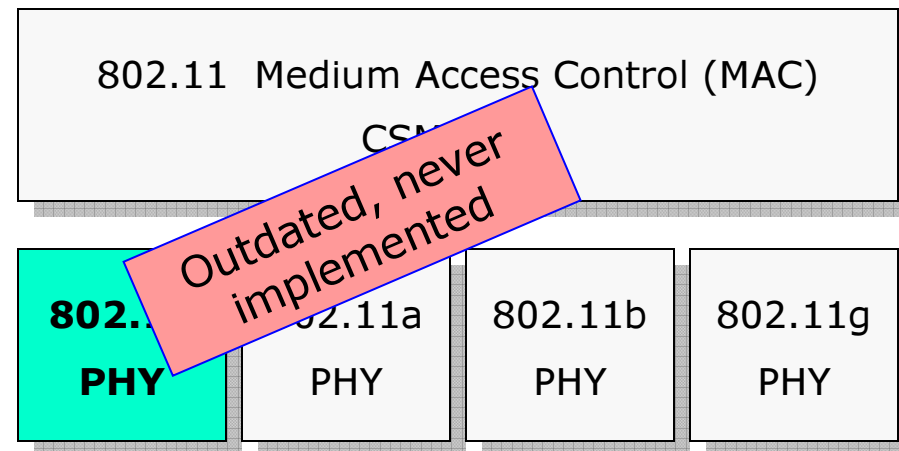
WLAN physical layer (1)

The original physical layer specified in 802.11 defines two signal formats:

FHSS (Frequency Hopping Spread Spectrum)

DSSS (Direct Sequence Spread Spectrum)

Data rates supported:
1 and 2 Mbit/s.



ISM band: 2.4 ... 2.4835 GHz

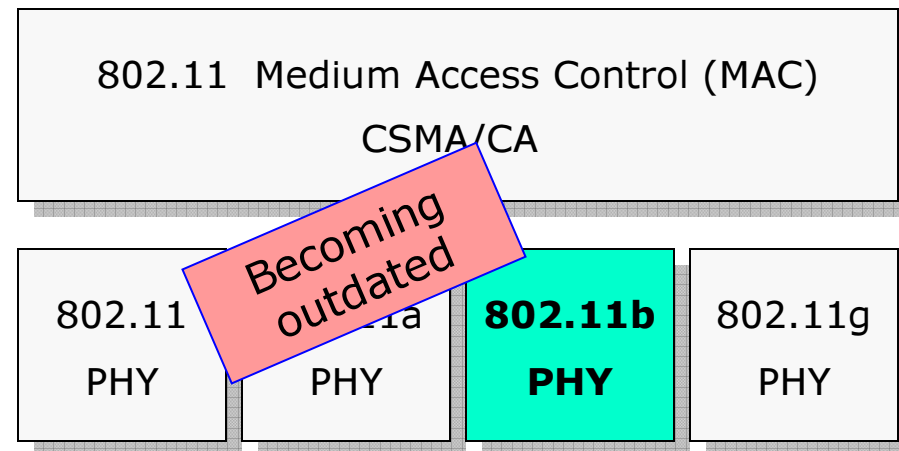


WLAN physical layer (2)

The first widely implemented physical layer was 802.11b that uses:

DSSS (Direct Sequence Spread Spectrum) like in 802.11 but with larger bit rates: 1, 2, 5.5, 11 Mbit/s

Automatic fall-back to lower speeds in case of bad radio channel.



ISM band: 2.4 ... 2.4835 GHz



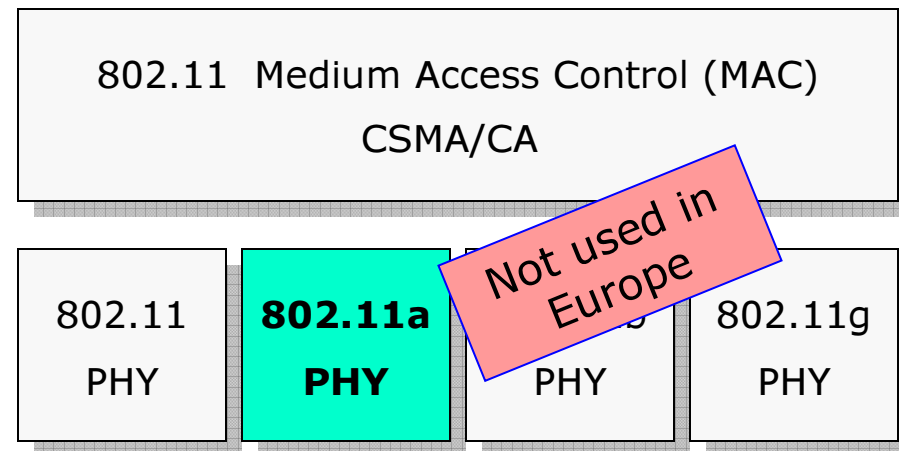
WLAN physical layer (3)

802.11a operates in the 5.8 GHz band. **This poses some problems in Europe***

The signal format is **OFDM** (Orthogonal Frequency Division Multiplexing)

Data rates supported:
Various bit rates from 6 to 54 Mbit/s.

*more in later presentation



5 GHz frequency band

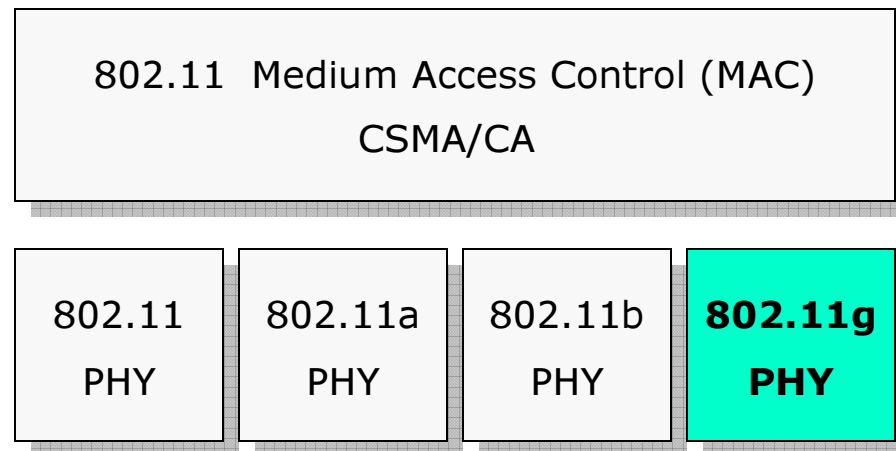


WLAN physical layer (4)

802.11g is the most recent physical layer, operating in the same band as 802.11b

The signal format is **OFDM** (Orthogonal Frequency Division Multiplexing)

Data rates supported:
Various bit rates from 6 to 54 Mbit/s (same as 802.11a)



ISM band: 2.4 ... 2.4835 GHz

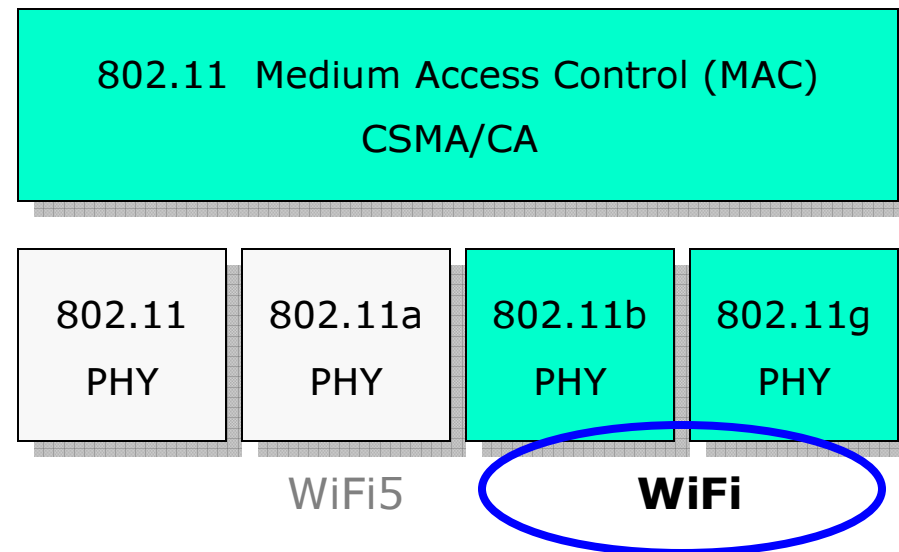


Wireless Fidelity (WiFi)

The WiFi certification program of the Wireless Ethernet Compatibility Alliance (WECA) addresses compatibility of IEEE 802.11 equipment

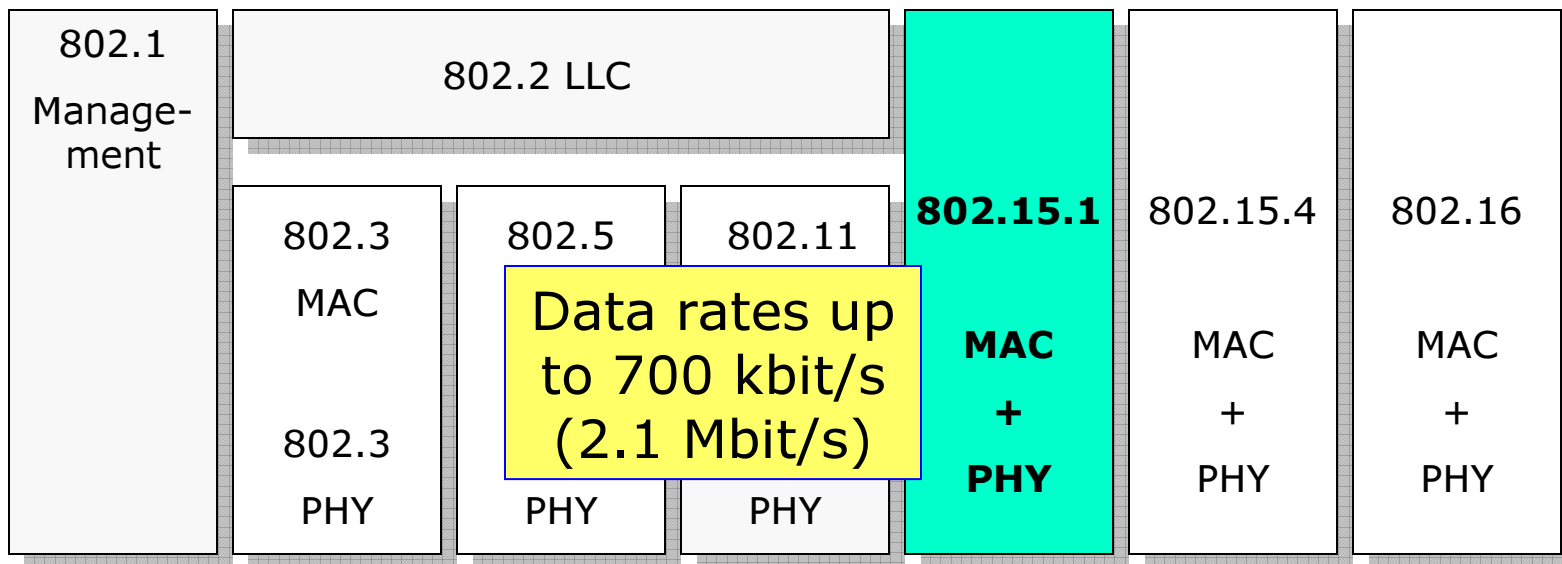
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WiFi ensures interoperability of equipment from different vendors.





Wireless Personal Area Network (WPAN)

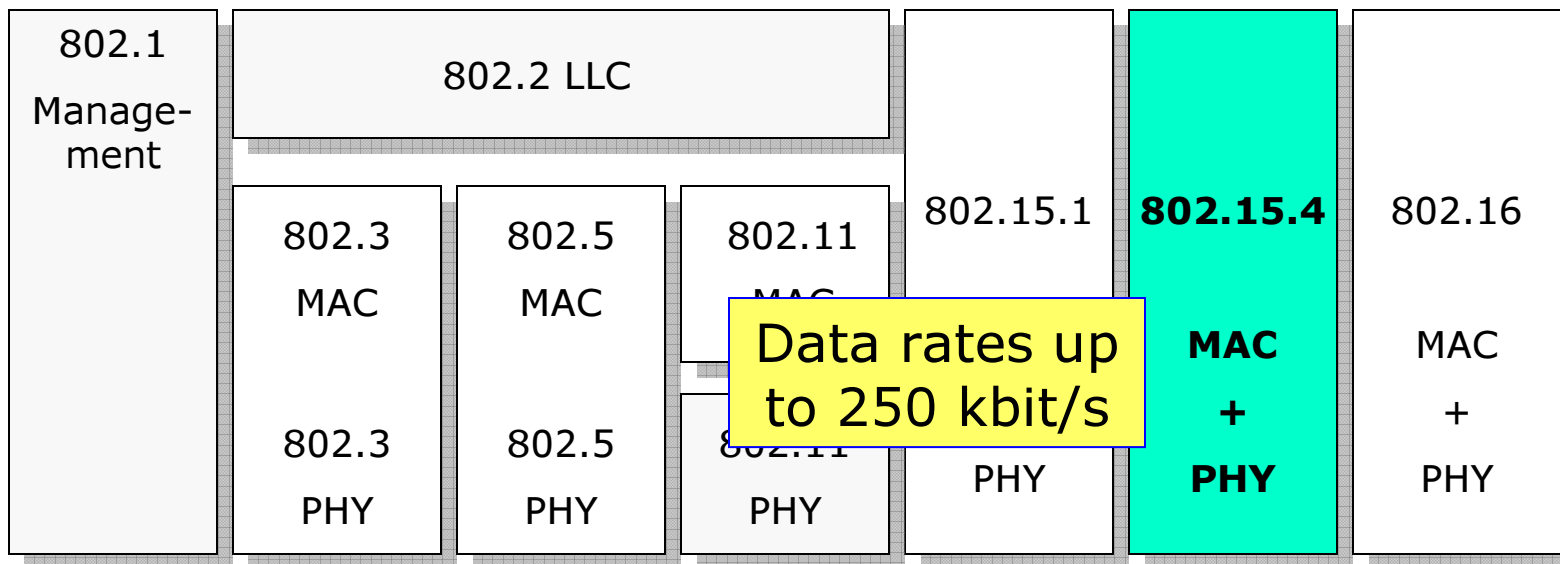


ISM band: 2.4 ... 2.4835 GHz

Bluetooth Special Interest Group (SIG)



Low-rate WPAN (LR-WPAN)

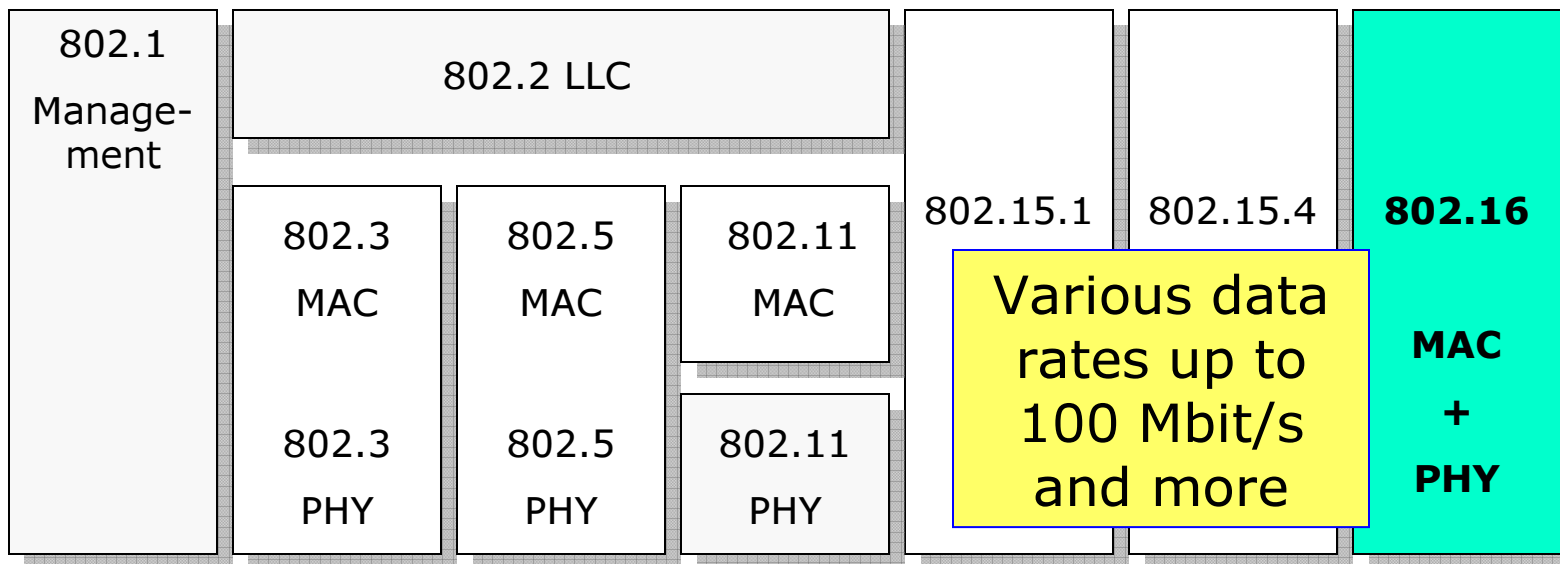


ISM band: 2.4 ... 2.4835 GHz

ZigBee Alliance



Wireless Metropolitan Area Network (WMAN)



Various frequency bands (not only ISM)

WiMAX



ISM frequency bands

ISM (Industrial, Scientific and Medical) frequency bands:

- 900 MHz band (902 ... 928 MHz)
- 2.4 GHz band (2.4 ... 2.4835 GHz)
- 5.8 GHz band (5.725 ... 5.850 GHz)

Anyone is allowed to use radio equipment for transmitting in these bands (provided specific transmission power limits are not exceeded) without obtaining a license.



ISM frequency band at 2.4 GHz

The ISM band at 2.4 GHz can be used by anyone as long as (in Europe...)

Transmitters using FH (Frequency Hopping) technology:

- Total transmission power < 100 mW
- Power density < 100 mW / 100 kHz

Transmitters using DSSS technology:

- Total transmission power < 100 mW
- Power density < 10 mW / 1 MHz

ETSI
EN 300 328-1
requirements



Free-space loss is dependent on frequency

The free-space loss L of a radio signal is:

$$L = \left(\frac{4\pi d}{\lambda} \right)^2 = \left(\frac{4\pi df}{c} \right)^2$$

where d is the distance between transmitter and receiver, λ is the rf wavelength, f is the radio frequency, and c is the speed of light. The formula is valid for $d \gg \lambda$, and does not take into account antenna gains (\Rightarrow Friis formula) or obstructing elements causing additional loss.



Free-space loss examples

For example, when d is 10 or 100 m, the free-space loss values (in dB) for the different ISM bands are:

	$d = 10$ m	$d = 100$ m
$f = 900$ MHz	$L = 51.5$ dB	$L = 71.5$ dB
$f = 2.4$ GHz	$L = 60.0$ dB	$L = 80.0$ dB
$f = 5.8$ GHz	$L = 67.7$ dB	$L = 87.7$ dB



Network topology (1)

Infrastructure network:

The wireless network has a fixed central element (base station, access point) that manages the network and through which all communication takes place.

Ad hoc network:

The wireless network has no (or a dynamically allocated) central element, so that the network topology can change over time without user intervention. Such a network is more flexible but also more difficult to manage.



Network topology (2)

<i>Network</i>	<i>Network topology</i>
IEEE 802.15.1 WPAN (Bluetooth)	Ad hoc (with dynamically allocated central element)
IEEE 802.15.4 LR- WPAN (ZigBee)	Ad hoc
IEEE 802.11 WLAN (WiFi)	Infrastructure (ad hoc also possible)
IEEE 802.16 WMAN (WiMAX)	Infrastructure



Multiplexing / multiple access / duplexing (1)

Multiplexing / multiple access

Signals to/from different users share a common channel using time division methods (TDM/TDMA, CSMA), frequency division methods (FDM/FDMA), or CDMA.

Duplexing:

The signals moving between two elements in opposite directions can be separated using time division duplexing (TDD) or frequency division duplexing (FDD). In the case of CSMA, duplexing is not relevant.



Multiplexing / multiple access / duplexing (2)

<i>Network</i>	<i>Multiplexing / MA / duplexing</i>
IEEE 802.15.1 WPAN (Bluetooth)	TDMA / TDD
IEEE 802.15.4 LR- WPAN (ZigBee)	CSMA/CA
IEEE 802.11 WLAN (WiFi)	CSMA/CA
IEEE 802.16 WMAN (WiMAX)	TDM/TDMA (down/uplink) / TDD or (semi-duplex) FDD



Maximum channel data rates

<i>Network</i>	<i>Maximum data rate</i>
IEEE 802.15.1 WPAN (Bluetooth)	1 Mbit/s (Bluetooth v. 1.2) 3 Mbit/s (Bluetooth v. 2.0)
IEEE 802.15.4 LR- WPAN (ZigBee)	250 kbit/s
IEEE 802.11 WLAN (WiFi)	11 Mbit/s (802.11b) 54 Mbit/s (802.11g)
IEEE 802.16 WMAN (WiMAX)	134 Mbit/s



Modulation / Signal spreading

<i>Network</i>	<i>Modulation / spreading method</i>
IEEE 802.15.1 WPAN (Bluetooth)	Gaussian FSK / FHSS
IEEE 802.15.4 LR- WPAN (ZigBee)	Offset-QPSK / DSSS
IEEE 802.11 WLAN (WiFi)	DQPSK / DSSS (802.11b) 64-QAM / OFDM (802.11g)
IEEE 802.16 WMAN (WiMAX)	128-QAM / single carrier 64-QAM / OFDM



Addressing

In a LAN environment, devices are logically separated using 48-bit globally unique MAC addresses:

Example: 00:90:4B:00:0C:72

00	90	4B	00	0C	72
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Four bits in a hexadecimal number

In IPv4 networks (e.g. Internet), nodes are logically separated using 32-bit globally unique IP addresses:

Example: 124.2.10.57

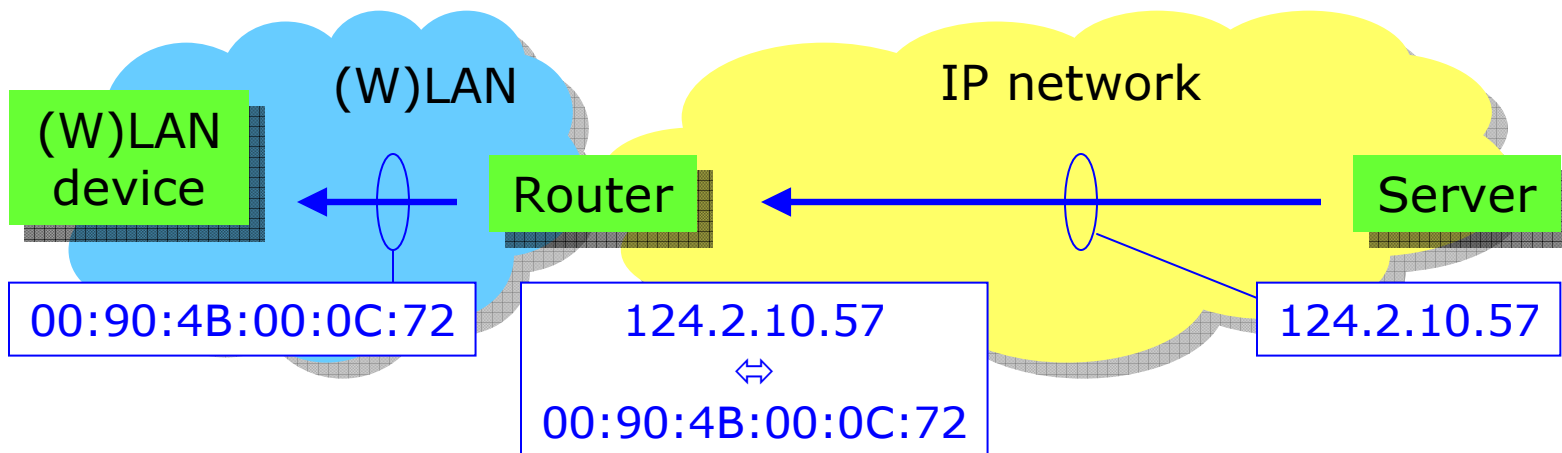
124	2	10	57
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Eight bits in a decimal number



Routing in a (W)LAN

Routing in a (W)LAN is based on MAC addresses, never IP addresses. A router (e.g. integrated with an access point) performs mapping between these two address types:





Address allocation

MAC addresses are associated with the hardware devices.

IP addresses can be allocated to (W)LAN devices either on a permanent basis or dynamically from an address pool using the Dynamic Host Configuration Protocol (DHCP).

The **DHCP server** may be a separate network element (or for example integrated into a RADIUS server that offers a set of additional features), or may be integrated with the address-mapping router and/or access point.

RADIUS = Remote Authentication Dial-In User Service



Network Address Translation (NAT)

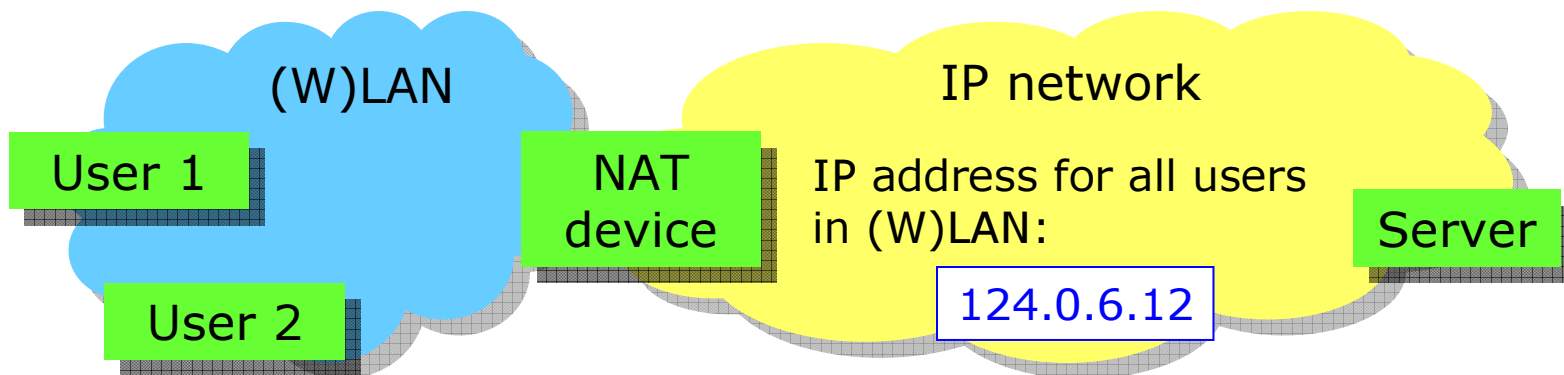
On the (W)LAN side of the network address translator (NAT device), different (W)LAN users are identified using private (reusable, globally not unique) IP addresses.

On the Internet side of the NAT device, only one (globally unique) IP address is used. Users are identified by means of different TCP/UDP port numbers.

In client - server type of communication, the application on the server is usually behind a certain TCP/UDP port number (e.g. 80 for HTTP) whereas clients can be allocated port numbers from a large address range.



NAT example



User 1 IP address 10.2.1.57

User 2 IP address 10.2.1.58

User 1 TCP port number 14781

User 2 TCP port number 14782



Case study: ADSL WLAN router

1) The ADSL connection to the wide area network (WAN) is allocated a globally unique IP address using DHCP.

2) We assume that the router has NAT functionality. Behind the router, in the private LAN network, wireless and cabled LAN devices are allocated private IP addresses, again using DHCP (this is a kind of "double DHCP" scenario).

Although routing in the LAN is based on MAC addresses, the IP applications running on the LAN devices still need their own "dummy" IP addresses.