IEEE 802.11 PCF

- A Point Coordinator (PC) resides in the Access Point and controls frame transfers during a Contention Free Period (CFP)
- Beacon at TBTT (Target Beacon Transmisison Time) from PC starts the CFP period.
- A CF-Poll frame is used by the PC to invite a station to send data (list maintained by the PC). **At least one CF-Poll** sent in a CFP (if list is not null)
- A CF-End frame is sent to end the CFP period.
- In between, data transfer takes place to and from PC to to and from one or more STA.
- The CFP alternates with a Contention Period (CP) in which data transfers happen as per the rules of DCF
- This CP must be large enough to send **at least one** maximum-sized packet including RTS/CTS/ACK

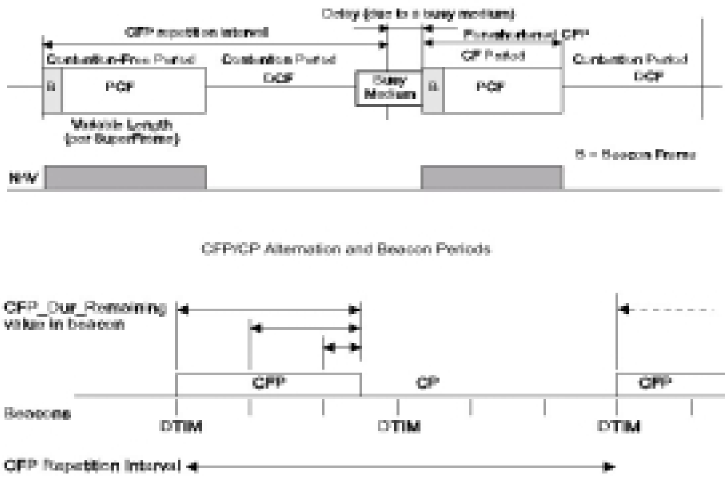
IEEE 802.11 PCF Access

- At the beginning of each CFP, the PC shall sense the medium. When the medium is determined to be idle for one PIFS period, the PC shall transmit a Beacon frame containing the CF Parameter Set element and a DTIM element.
- After the initial beacon frame, the PC shall wait for at least one SIFS period, and then transmit one of the following:
  - a data frame,
  - a CF-Poll frame,
  - a Data+CF-Poll frame, or
  - a CF-End frame.
- If the CFP is null, i.e., there is no traffic buffered and no polls to send at the PC, a CF-End frame shall be transmitted immediately after the initial beacon.
- STAs receiving directed, error-free frames from the PC are expected to respond after a SIFS period

IEEE 802.11 PCF and NAV

- STAs at each TBTT receives CF parameter set (within a beacon) which contains CF-Duration.
- STA set their NAV for that period so that they do not try to acquire channel in during CFP
- STA s reset their NAV on receiving CF-END frame.

IEEE 802.11 PCF



IEEE 802.11 PCF (example)

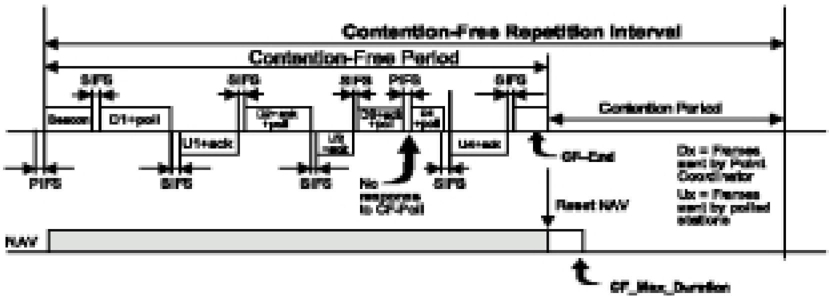


Figure 62—Example of PCF frame transfer

IEEE 802.11 PCF (frames)

The PC may transmit any of the following frame types to CF Pollable STAs:

- — **Data**, used to send data from the PC
- — **Data+CF_ACK**, used to send data from the PC nd the PC needs to acknowledge the receipt of a frame received from a CF-Pollable STA
- — **Data+CF_Poll**, used to send data from the PC when the addressed recipient is the next STA to be permitted to transmit during this CFP and there is no previous frame to acknowledge;
- — **Data+CF_ACK+CF_Poll,**
- — **CF_Poll,**
- — **CF_ACK+CF_Poll,**
- — **CF_ACK,**
- — Any management frame that is appropriate for the AP to send under the rules for that frame type.

IEEE 802.11 PCF

- Polling List
  - The polling list is maintained by PC for CF-Poll-able STAs
  - The STA registers with polling list of PC with *association* message and gets an AID i..e.*Association ID*, from the PC
- Polling List Processing
  - The PC shall send a CF-Poll to at least one STA during each CFP when there are entries in the polling list.
  - Poll by ascending AID value.
- Polling List Update Procedure
  - Association/ Re-association

IEEE 802.11 DCF vs. PCF throughput

- Overheads to throughput and delay in DCF mode come from losses due to collisions and backoff
- These increase when number of nodes in the network increases
- RTS/CTS frames cost bandwidth but large data packets (>RTS threshold) suffer fewer collisions
- RTC/CTS threshold must depend on number of nodes
  - Collision risk
  - Frame duration (RTS threshold)
- Overhead in PCF modes comes from wasted polls
- Polling mechanisms have large influence on throughput

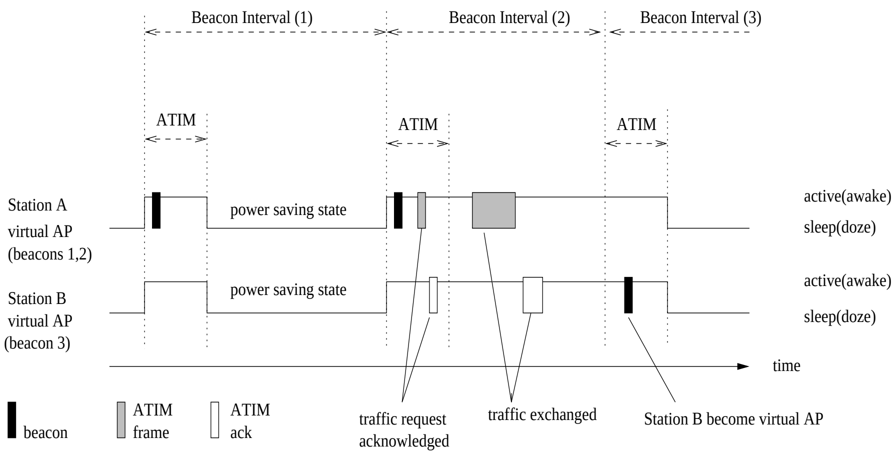
IEEE 802.11 PCF (power save)

- Every beacon contains TIM (traffic indication map), a virtual bitmap along with time stamp.
- STAs wake up to listen beacon (by the STA's ListenInterval parameter). PS mode is intimated to AP during Association process
- If STA sees in TIM that a packet is buffered for it in AP, it sends a short CF-Poll to AP within CFP

IEEE 802.11 power saving

- Low-power mode: Network Allocation Vectors (NAV)
  - updated by each station listening RTS/CTS
  - allow virtual carrier sensing and doze mode
- Transmission power control
  - Tx power levels:
    - *1000 mW (USA), 100 mW (Europe), 10 mW (Japan)*
- Buffering
  - power saving stations (PSS) notify the AP
  - AP buffers frames for PSS and sends Traffic Information Map (TIM) on Beacon frames
  - beacon frames contain DTIM (delivery TIM)
- Power-aware Contention control

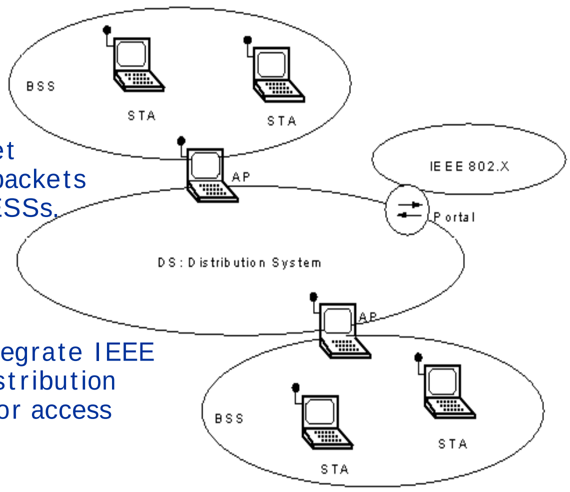
IEEE 802.11 power saving (ad hoc scenario)



Range Extension between BSS cells and DS

IEEE 802.11: Distribution System (DS)

AP: Access Point
BSS: Basic Service Set
ESS: Extended Service Set
DS: Network to transmit packets between BSSs to realize ESSs.

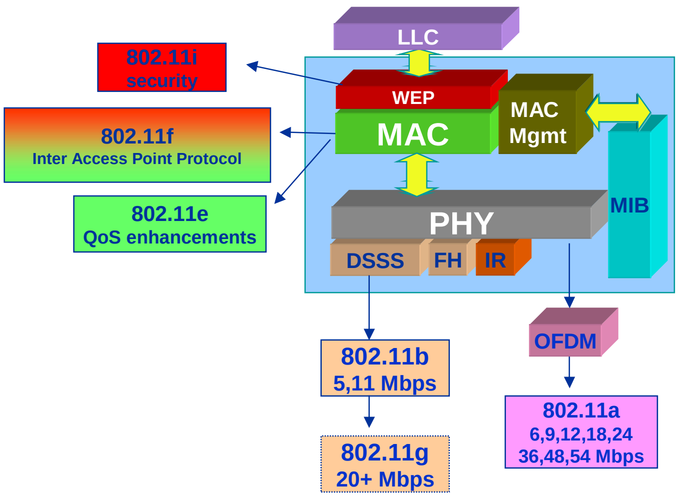


Portal: logical entity to integrate IEEE 802.11 network and the distribution system (dedicated device or access point)

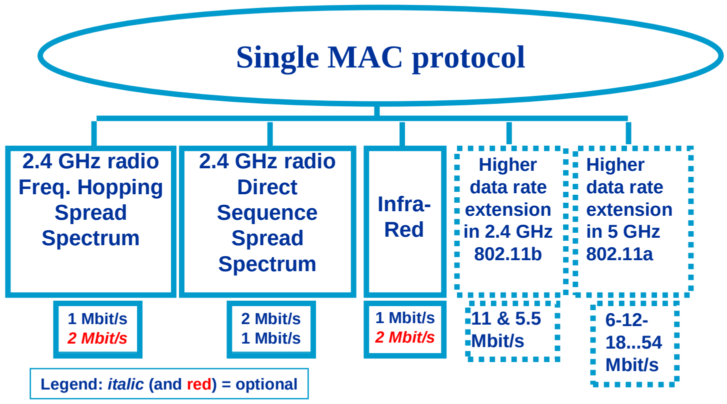
IEEE 802.11 Wireless LAN

- **Technical features: 802.11 Base Standard (1997)**
  - **3 PHY** (physical) layer definitions:
- **FHSS, DSSS, (IR)**
  - 1-2 Mbps
  - **2.400-2.4835 GHz (unlicensed ISM band)**
- **Technical features: 802.11 Evolution a and b (1998)**
  - **IEEE 802.11a**:
  - extension of performance and range
  - support voice, data and video applications
  - data rates: 6, 12, 18, 24, 36, 48, 54 Mbps
  - DSSS in the 5GHz band

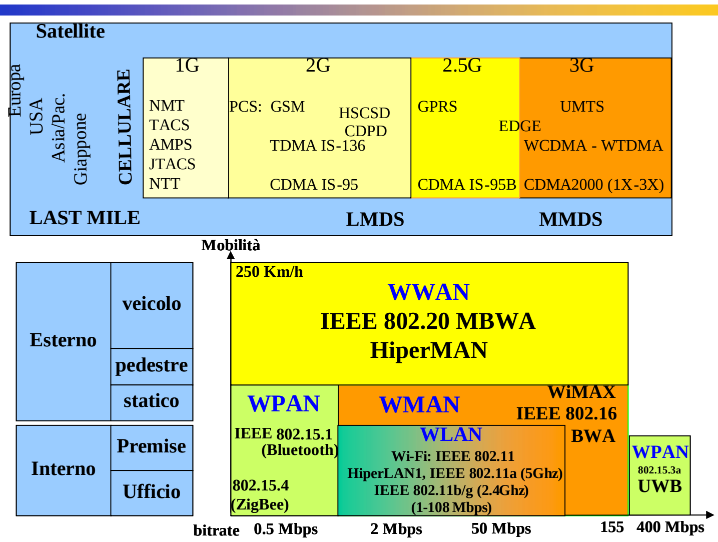
IEEE 802.11 status



IEEE 802.11 Standard PHY and MAC



Tecnologie e Standard (1)



Tecnologie e Standard (2)

Gruppi di standardizzazione IEEE 802.11	Descrizione
IEEE 802.11	lo standard originale: bitrate da 1 a 2 Mbps, spettro 2.4 Ghz, livello fisico sia radio che infrarosso
IEEE 802.11a	54 Mbit/s, 5 GHz, lanciato nel 2001
IEEE 802.11b	sviluppo di IEEE 802.11 (1999), da 5.5 a 11 Mbps
IEEE 802.11d	estensioni per roaming internazionale
IEEE 802.11e	estensioni per qualità del servizio
IEEE 802.11f	standard per Inter Access Point Protocol (IAPP[2])
IEEE 802.11g	54 Mbit/s, 2.4 GHz, retrocompatibile con IEEE 802.11b
IEEE 802.11h	selezione dinamica dei canali e controllo della potenza trasmissiva (compatibile con direttive europee)
IEEE 802.11i	integrazioni e estensioni per la sicurezza (2004)
IEEE 802.11j	estensioni per direttive giapponesi
IEEE 802.11k	estensioni per misurazione dei parametri radio
IEEE 802.11n	estensioni per throughput elevati (oltre 200 Mbps) mediante tecnologia MIMO (trasmettitori e ricevitori multipli)
IEEE 802.11p	accesso wireless per sistemi veicolari (WAVE)
IEEE 802.11r	estensioni per roaming veloce
IEEE 802.11s	estensioni per reti wireless mesh
IEEE 802.11t	metodi e metriche per misurazione e predizione delle prestazioni
IEEE 802.11u	internetworking con reti non 802.11 (cellulari)
IEEE 802.11v	gestione e amministrazione delle reti wireless

Tecnologie e Standard (3)

	UWB	Bluetooth	Wi-fi	Wi-fi	Wi-fi	WiMAX	WiMAX	EDGE	CDMA	UMTS
Standard	802.15.3a	802.15.1	802.11a	802.11b	802.11g	802.16d	802.16e	2,5G	3G	3G
contesto	WPAN	WPAN	WLAN	WLAN	WLAN	WMAN (fisso)	WMAN (mobile)	WWAN	WWAN	WWAN
MAX bitrate	110-480 Mbps	720 Kbps	54 Mbps	11-22 Mbps	54-108 Mpbs	75 Mbps (20 Mhz)	30 Mbps (10 Mhz)	384 Kbps	2,4 Mbps	10 Mbps
distanza	10 m	10 m	100 m	100 m	100 m	10 km	5 km	5 km	5 km	5 km
spettro	7,5 Ghz	2,4 Ghz (ISM)	5 Ghz	2,4 Ghz (ISM)	2,4 Ghz (ISM)	11 Ghz	2-6 Ghz	1800 Mhz	multi	multi

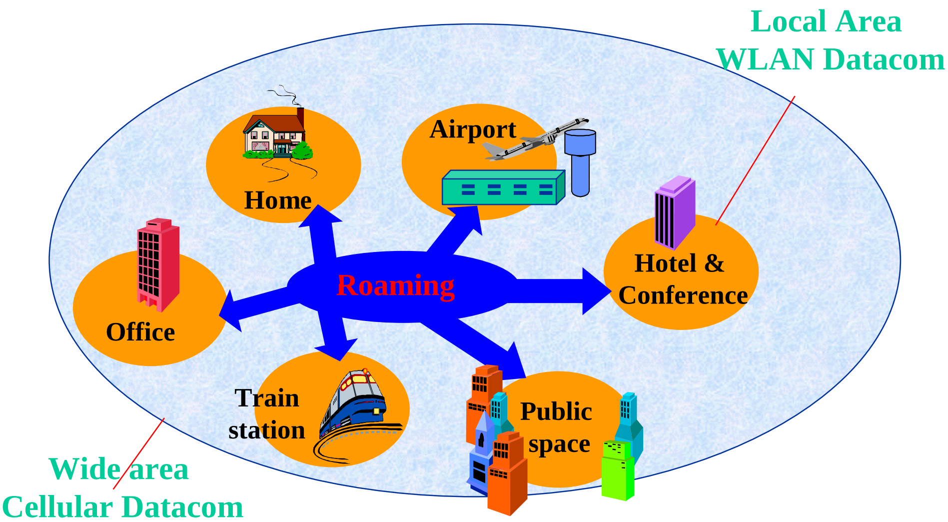
Hiperlan/2

- European Telecommunications Standardisation Institute [ETSI] specification
- Broadband Radio Access Networks [BRAN] project
- Hiperlan/2 Global Forum [H2GF]:
  - open industry forum to create a global standard for high speed WLAN products

What is HiperLAN/2?

- A next generation Wireless LAN technology
- Operates in the **5 GHz** band, with a portion of dedicated spectrum allocated world-wide
- Broadband communication, up to **54 Mbit/s** transmission rate at radio interface
- **Connection-oriented** with support for **QoS**

HiperLAN/2 - The Vision



Goals

- Certified interoperable products on the market early 2002
- Corporate and public networks as the first target
- Ensure spectrum allocated on all major markets
- Wireless LAN = HiperLAN/2

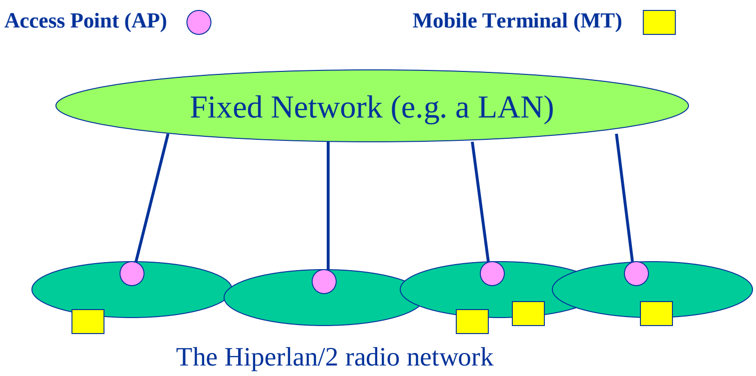
Hiperlan/2

- Timetable:
  - *final specification: Sept. 1999*
  - *test: year 2000*
  - *first product: year 2001 (full market: year 2002)*

- World-wide market estimate for WLAN products [H2GF]:
  - *$ 1 Bn (year 2000)*
  - *$ 2 Bn (year 2002) (not counting embedded solutions)*

Hiperlan/2

- The Hiperlan/2 network architecture:



Hiperlan/2

- Features of Hiperlan/2:
  - *High-speed transmission*
    - up to 54 Mbit/s (25Mbit/s on Layer 3)
    - Orthogonal Frequency Digital Multiplexing (OFDM)
  - *Connection oriented transmission*
    - time division multiplexed (TDM) connections established prior to the transmission between MT and AP
    - Point to Point (bidirectional) and Point to MultiPoint (AP to MT) connection types
    - dedicated broadcast channel (AP to MTs)
    - connection oriented transmission allows QoS support

Hiperlan/2

- Features of Hiperlan/2: (continue)
  - *Quality of Service (QoS) support:*
    - QoS can be managed for each connection, supporting bandwidth, delay, jitter, bit error rate, etc.
    - support for Priority levels between connections
    - (QoS + high TX rate) facilitates multi-type data streams: video, voice and data
  - *Automatic frequency allocation:*
    - no manual frequency planning required (e.g. as in GSM cellular networks)
    - APs automatically select the radio channel for TX by minimizing interference with the environment, and neighboring APs coverage areas

Hiperlan/2

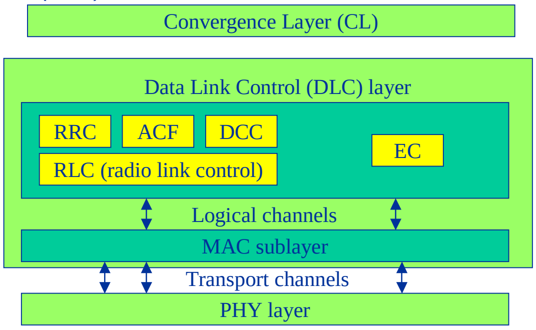
- Features of Hiperlan/2: (continue)
  - *Security support:*
    - MT association with the AP covering the area
    - Authentication supported (provided some directory service function)
    - Encryption supported against eaves-dropping and attacks
  - *Mobility support:*
    - Handover (defined on a best SNR policy): packet loss and re-association can occur

Hiperlan/2

- Features of Hiperlan/2: (continue)
  - *Network and Application independency:*
    - Hiperlan/2 protocol stack is flexible
    - can be used as "last hop" wireless segment of Ethernet, or access network to 3G cellular network
    - All apps. running over a fixed infrastructure are supported
  - *power save:*
    - MT-initiated negotiation of sleep (low energy) periods
    - AP bufferizes traffic to sleeping MT and manages Wake-up signals

Hiperlan/2

- Hiperlan/2 protocol architecture:
  - **Convergence layer (CL)**
  - **Data Link Control (DLC)**
    - *Association Control Function (ACF)*
    - *DLC user Connection Control (DCC)*
    - *Radio Resource Control (RRC)*
    - *Error Control (EC)*
  - **Physical (PHY)**



Hiperlan/2

- **Convergence layer (CL):**
  - adapts service request from upper layers to the service offered by DLC
  - converts higher layer packets to fixed size packets used within the DLC
  - makes Hiperlan/2 suitable as radio access network for a diversity of fixed networks:
    - *Ethernet, IP-based, UMTS, etc. (**packet based CL**)*
    - *ATM (**cell-based CL**)*

Hiperlan/2

- **MAC sublayer**
  - Logical Transport Channels: on top Transport Channels
  - SBCH: slow broadcast channel (downlink)
    - *encryption seeds, handover acks, MAC-id to new assoc. MTs*
  - DCCH: dedicated control channel (bidirectional)
    - *signalling for connection control and association*
  - UDCH: user data channel (bidirectional)
    - *user data PDUs, ARQ (acks), reliable ordered delivery for Convergence Layer CL*
  - LCCH: link control channel (bidirectional)
    - *info for Error Control (EC) in UDCH*
  - ASCH: association control channel (uplink)
    - *(re)association request during handover by MTs*

Hiperlan/2

- **MAC sublayer**
  - BCH: broadcast channel (downlink: BS to MTs)
    - *LAN and AP Identifiers, Ptx levels, begin/end time of FCH, RCH*
  - FCH: Frame control channel (downlink)
    - *indicates resource allocation in Downlink, Uplink, RCH phases*
  - ACH: Access feedback channel (downlink)
    - *reports results of previous RCH-transmissions*
  - RCH: Random access channel (uplink)
    - *contention slots for DL,UL resource request from MTs to AP*

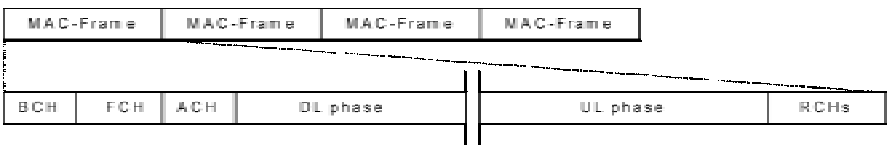


Figure 3: Basic MAC frame structure

Hiperlan/2

- **MAC sublayer**
  - Uplink UL,downlink DL (bidirectional)
    - *sequence of PDU trains*
    - *DLC user PDU (U-PDU): 54 Bytes (48 Bytes payload)*
      - referred to as Long transport CHannel (LCH)
    - *DLC control PDU (C-PDU): 9 Bytes*
      - referred to as Short transport CHannel (SCH)

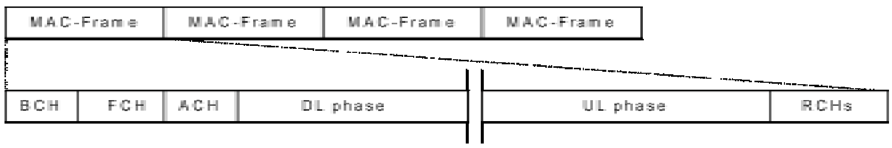
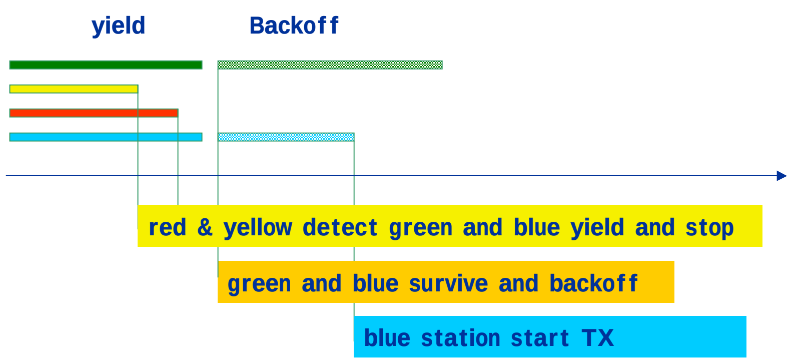


Figure 3: Basic MAC frame structure

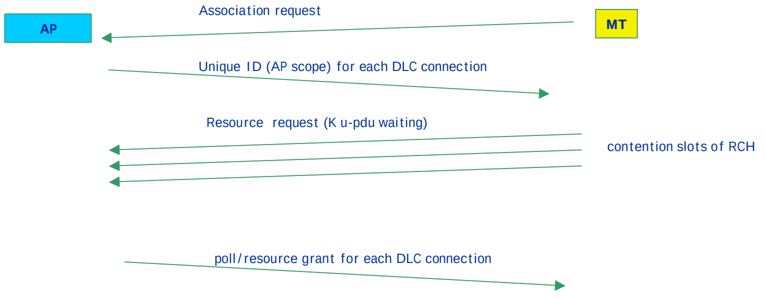
Hiperlan/2

- **MAC sublayer: the RCH contention based access (MT to BS)**
  - Two Elimination phases



Hiperlan/2

Association and transmission



Hiperlan/2

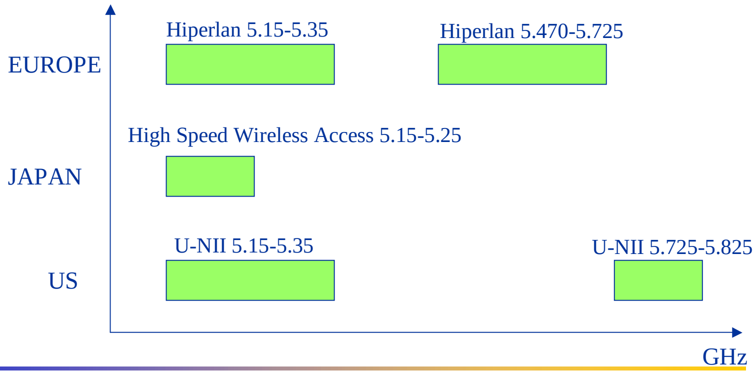
PHY layer: data rates

- OFDM: Orthogonal Frequency Division Multiplexing
  - *good for highly dispersive channels*
  - *channel spacing 20Mhz*
    - high bit rate per channel
    - 19 channels in Europe's spectrum
    - 52 subcarriers per channel (48xData, 4xpilot)

Mode	Modulation	Code rate	PHY bit rate	bytes/OFDM symb.
1	BPSK	½	6 Mbps	3.0
2	BPSK	¾	9 Mbps	4.5
3	QPSK	½	12 Mbps	6.0
4	QPSK	¾	18 Mbps	9.0
5	16QAM	9/16	27 Mbps	13.5
6	16QAM	¾	36 Mbps	18.0
7	64QAM	¾	54 Mbps	27.0

Hiperlan/2

- **Single cell coverage area**:
  - 30 meters (indoor), 150 meters (outdoor)
- **Spectrum allocation**: in 5 GHz band
  - world-wide roaming in 5.15 - 5.25 GHz



Hiperlan/2

- Example applications:
  - **Corporate LAN**:
    - *extension (last segment) of Ethernet LAN and IP routers*
  - **Hot Spots**: airports, hotels, conference sites
  - **access to 3G cellular networks**
    - *covering hot spots and Wide areas with W-CDMA*
  - **Home network**:
    - *wireless infrastructure for home devices*
    - *QoS and high-speed support video streams and datacom applications*

Hiperlan/2

- Performance test:
  - influenced by number of frequencies, propagation, interference, link adaptation, etc.
  - **Office environment** test:
    - *< 20Mbps [ETSI requirement] (no link adaptation)*
    - ***up to 35 Mbps** (with link adaptation)*
  - **Exhibition hall**:
    - ***> 20 Mbps** (with link adaptation)*

IEEE 802.11 vs. HiperLAN

Characteristic	802,11	802.11b	802.11a	HiperLAN/2
Spectrum	2.4 GHz	2.4 GHz	5 GHz	5 GHz
~Max physical rate	2 Mb/s	11 Mb/s	54 Mb/s	54 Mb/s
~Max data rate, layer 3	1.2 Mb/s	5 Mb/s	32 Mb/s	32 Mb/s
Medium access control/Media sharing	Carrier sense - CSMA/CA			Central resource control/ TDMA/TDD
Connectivity	Conn.-less	Conn.-less	Conn.-less	Conn.-oriented
Multicast	Yes	Yes	Yes	Yes[1]
QoS support	(PCF)[2]	(PCF)[2]	(PCF)[2]	ATM/802.1p/RSVP/ DiffServ (full control)
Frequency selection	Frequency-hopping or DSSS	DSSS	Single carrier	Single carrier with Dynamic Frequency Selection
Authentification	No	No	No	NAI/IEEE address/X.509
Encryption	40-bit RC4	40-bit RC4	40-bit RC4	DES, 3DES
Handover support	(No)[3]	(No)[3]	(No)[3]	(No)[4]
Fixed network support	Ethernet	Ethernet	Ethernet	Ethernet, IP, ATM, UMTS, FireWire, PPP[5]
Management	802.11 MIB	802.11 MIB	802.11 MIB	HiperLAN/2 MIB
Radio link quality control	No	No	No	Link adaptation

1. Two different modes supported, multicast via a dedicated MAC-ID (same as for 8202.11) and N*unicast for improved quality.
2. Point Control Function, a concept defined in 802.11 to allow certain time slots being allocated for realtime-critical traffic.
3. Requires signalling over the fixed network, which is still proprietary.
4. Requires signalling over the fixed network, to be specified by H2GF.
5. Ethernet supported in first release.