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| Re: | This contribution is submitted in response to call for contributions from the WirelessHUMAN Study Group chair for submissions of contributions to develop the PAR request for a WirelessHUMAN standard. |
| Abstract | The contribution identifies the key parameters of the two WLAN standards, IEEE802.11a and HIPERLAN/2. Applicability of these two standards for WirelessHUMAN systems is analyzed. As the conclusion we propose a way to proceed from the basis of existing standards to a WirelessHUMAN PAR and new air interface standard. |
| Purpose | The purpose is to focus the coming PAR by limiting the number of possible standard candidates into minimum. The PAR written by the Study Group should emphasize the applicability of the systems most suitable for a WirelessHUMAN system. |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

# Applicability of IEEE802.11 or HIPERLAN/2 for WirelessHUMAN Systems

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## 1 Introduction

This contribution gives an overview of the two 5 GHz WLAN standards: IEEE802.11a and HIPERLAN/2 from ETSI/BRAN. One of the major tasks of the study group is to study the feasibility of the existing and evolving standards for the WirelessHUMAN systems. The contribution is to support this task and to help the study group to write a PAR by narrowing the scope of the coming standardization activity.

## 2 Basics of the 5 GHz WLAN standards

The basics of the two latest 5 GHz WLAN standards, IEEE802.11a and HIPERLAN/2, are introduced in this section. This system overview is an introduction to more comprehensive studies of applicability of some specific functionality in the following section.

### 2.1 HIPERLAN/2

The basic approach taken by the ETSI project BRAN was to standardize only the radio access network and some of the convergence layer functions to different core networks. The core network specific functions were left to the corresponding fora (e.g., ATM Forum, IETF and other ETSI projects). This is illustrated in Figure 1 below [1].

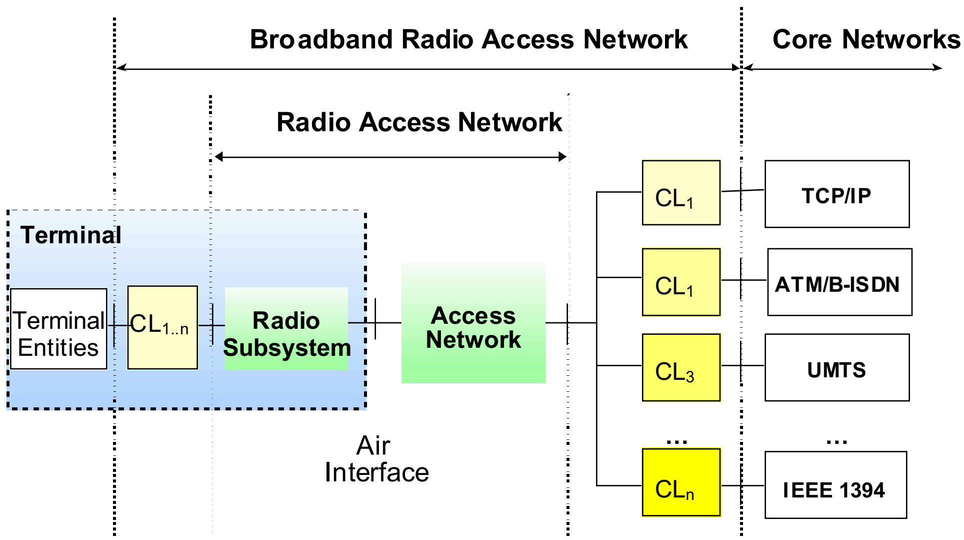



Figure 1. HIPERLAN/2 reference model.

A HIPERLAN/2 network consists typically of a number of APs each of which covers a certain geographic area. Together they form a radio access network with full or partial coverage of an area of almost any size. The coverage areas may or may not overlap each other, thus simplifying roaming of terminals inside the radio access network. Each AP serves a number of MTs which have to be associated to it.

HIPERLAN/2 supports two basic modes of operation:

1. Centralized mode: an AP is connected to a core network which serves the MTs associated to it. All traffic must pass the AP.
2. Direct mode: the MAC is still controlled by a central controller but this controller needs not necessarily be connected to a core network. The terminals may exchange data directly via the air, without passing the central controller.

The basic protocol stack on the AP side and its functions are shown in Figure 2. It consists of the PHY layer on the bottom, the DLC layer in the middle and the convergence layer on top. The CL offers a service to the higher layers which are out of the scope of this document.

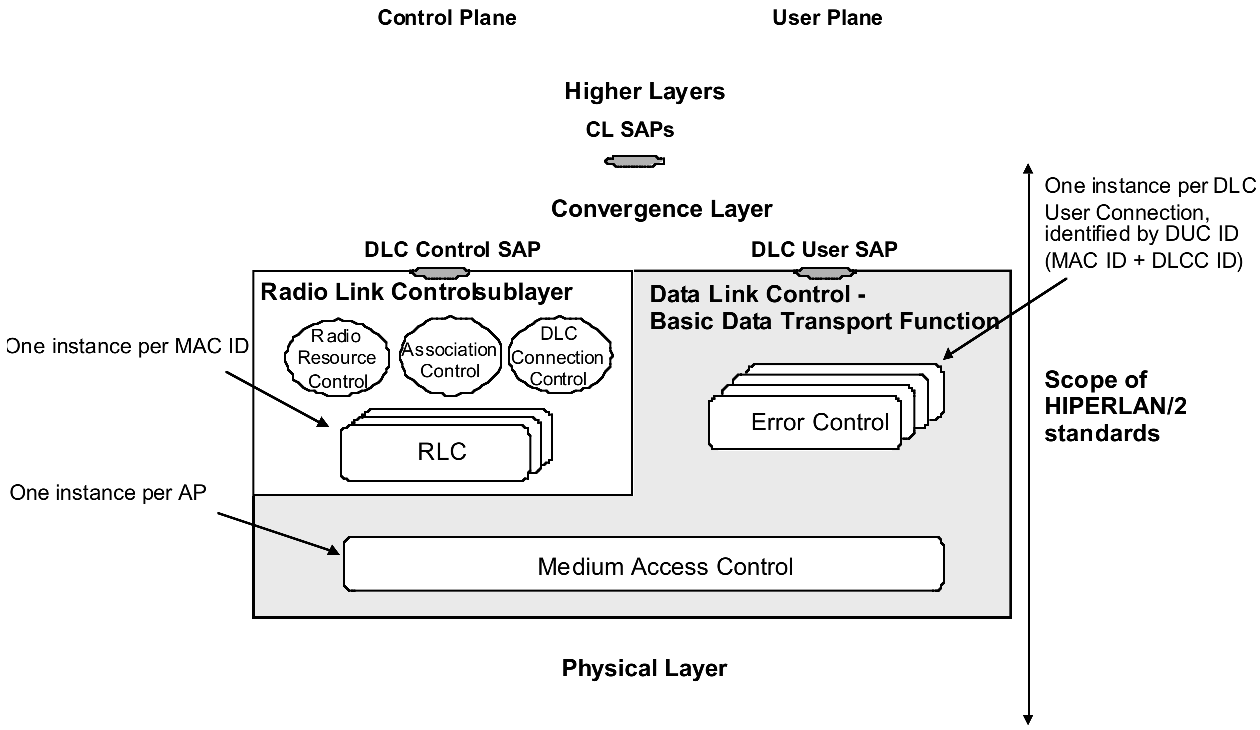



Figure 2. HIPERLAN/2 protocol stack.

The Physical layer delivers a basic data transport function by providing means of a baseband modem and a RF part. The baseband modem will also contain a forward error correction function.

The DLC layer consists of the Error Control function (EC), the Medium Access Control function (MAC) and the Radio Link Control sublayer (RLC). It is divided in the data transport functions, located mainly on the right hand side, and the control functions on the left hand side.

The user data transport function on the right hand side is fed with user data packets from the higher layers via the User Service Access Aoint (U-SAP). This part contains the Error Control (EC) which performs an ARQ (Automatic Repeat Request) protocol. The DLC protocol operates connection oriented which is shown by multiple connection end points in the U-SAP. In case the higher network is connection oriented, DLC connections can be created and released dynamically. In case the higher layer is connectionless, at least one DLC connection must be set up which handles all user data.

The left part contains the Radio Link Control Sublayer (RLC) which delivers a transport service to the DLC Connection Control (DCC), the Radio Resource Control (RRC) and the Association Control Function (ACF).

### 2.1.1 MAC

The MAC scheme is based upon a centrally scheduled TDMA/TDD scheme; i.e. the AP controls all transmissions over the air. The basic structure on the air interface generated by the MAC is shown in Figure 3. It consists of a sequence of MAC frames of equal length with 2 ms duration. Each MAC frame consists of several phases:

- Broadcast phase (BC) for general announcements and for the information about the structure of the ongoing frame, containing the exact position of all following emissions, their usage and content type.
- Downlink phase (DL) mainly for user specific control information and user data, transmitted from AP to MTs.

- Uplink phase (UL) for control and user data from the MTs to the AP. The MTs have to request bandwidth for one of the following frames in order to get resources granted by the AP.
- Direct Mode Phase (DM) for traffic between MTs without direct involvement of the AP. The AP is indirectly involved by receiving Resource Requests from MTs for these connections and transmitting Resource Grants.
- Random access phase (RA) for the transmission of control information of such MTs' to which no capacity has been allocated in the UL phase

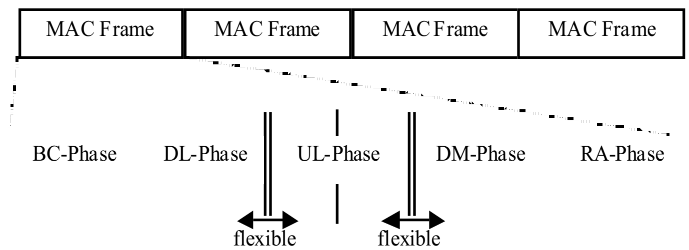



Figure 3. Basic MAC frame format

The DL and UL phases consist of two types of packets.

1. The long packets have a size of 54 Bytes and contain control or user data.
2. The short packets with a size of 9 bytes contain only control data and are always generated by the DLC or RLC. They may contain resource requests in the uplink, ARQ messages like acknowledgements and discard messages or RLC information.

### 2.1.2 PHY layer

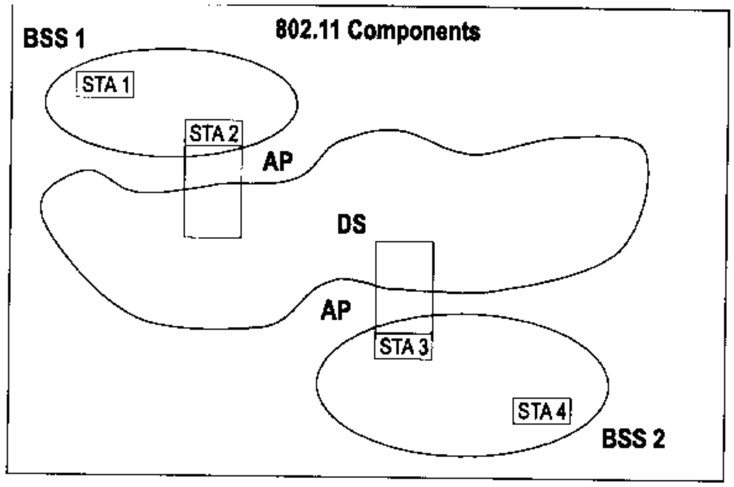
HIPERLAN/2 PHY layer is based on orthogonal frequency division multiplexing (OFDM). The main parameters are summarized as follows:

- Number of sub-carriers: 64.
- Number of used sub-carriers: 52, where 48 sub-carriers are used for data and the rest for pilots.
- Channel Spacing: 20 MHz.
- Sampling rate: 20 Msamples/s.
- Guard interval: 800 ns default mode corresponding to 16 time samples; 400 ns as an option (e.g. for the home environment).
- Sub-carrier modulation: BPSK, QPSK, 16QAM and optionally 64QAM.
- Sub-carrier demodulation: Coherent.
- Mandatory Forward Error Correction: a rate 1/2 mother convolutional code (9/16 and 3/4 by code puncturing).
- Supported data rates: 6, 9, 12, 18, 27, 36, 54 Mbit/s.
- Interleaving: Block interleaving with the size of one OFDM symbol.
- Oscillator accuracy: +/- 20 ppm with a reference oscillator for generation of RF and time-base clock.

## 2.2 IEEE802.11a

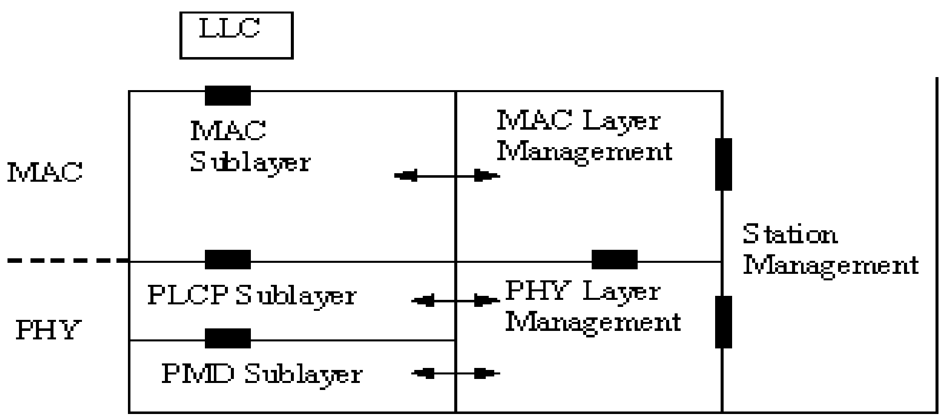
The 802.11 architecture consists of several components that interact to provide a wireless LAN that supports station mobility transparently to upper layers [2]. The basic service set (BSS) is the basic building block. A BSS can be considered as a coverage area within which stations of the BSS may communicate with each other. The most basic type of 802.11 LAN is independent BSS (IBSS), a.k.a. an ad hod network. This mode of operation is possible when stations are able to communicate directly.

For BSS interconnections there is a specific architectural component, distribution system (DS), in the standard. An access point (AP) is a station that provides access to the DS in addition to acting as a station. Basic architecture of the IEEE 802.11 is shown in Figure 4.




system.

The IEEE802.11a standard emphasizes the separation of the system into two major parts: the MAC of the data link layer and the PHY. The layers and sublayers described in the standard are shown in Figure 5.



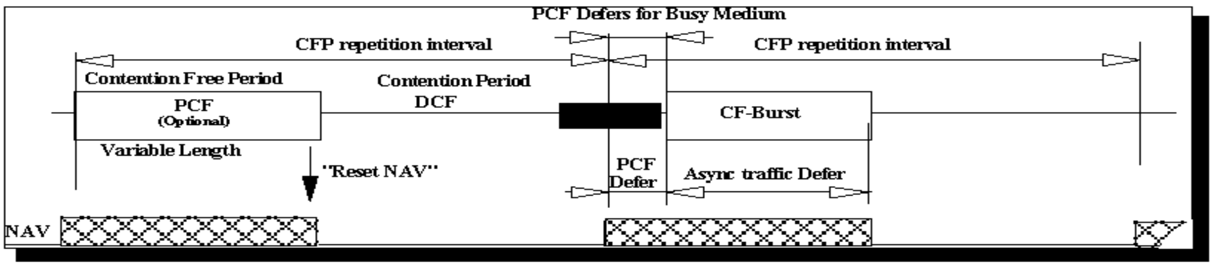

## 2.2.1 MAC

The 802.11 MAC is based on a fundamental access method called DCF (distributed coordination function), a.k.a. CSMA/CA. The DCF shall be implemented in all STAs. For a STA to transmit, it shall sense the medium to determine if another STA is transmitting. If the STA determines that the medium is idle for a certain time it may start transmission. If the medium is busy, the STA shall defer until the medium is determined to be idle once again for a certain time. After this short time period (min 34 μs), the STA shall invoke backoff procedure and defers for a random time period. Through this kind of contention procedure all the STAs get a chance for a transmission during a contention period (CP).

The 802.11 MAC may also incorporate an optional access method called a PCF, point coordination function. It is usable only on infrastructure network configurations. This access method uses a point coordinator (PC), which shall operate at the access point (AP) of the BSS. The PC determines which STA currently has the right to transmit. Thus the PCF forms the basis of a contention free period (CFP) and contention free transfer protocol. STAs are polled and they may transmit only when polled.

The basic MAC architecture is shown in Figure 6 and the CFP/CP alternation is illustrated in Figure 7.

Figure 6. MAC architecture.




### 2.2.2 PHY layer

The PHY layer is similar to the one of HIPERLAN/2. It is based on OFDM with 52 sub-carriers and 20 MHz channel spacing. The other main parameters are summarized as follows:

- Sampling rate: 20 Msamples/s.
- Guard interval: 800 ns corresponding to 16 time samples
- Sub-carrier modulation: BPSK, QPSK, 16QAM and 64QAM.
- Sub-carrier demodulation: Coherent.
- Forward Error Correction: a rate 1/2 mother convolutional code (2/3 and 3/4 by code puncturing).
- Supported data rates: 6, 9, 12, 18, 24, 36, 48, 54 Mbit/s.
- Interleaving: Block interleaving with the size of one OFDM symbol.
- Oscillator accuracy: +/- 20 ppm with a reference oscillator for generation of RF and time-base clock.

There are only very few minor differences between the PHY layers of the two WLAN standards and hereafter in the document we'll call them jointly as WLAN PHY.

## 3 WLAN MAC for the WirelessHUMAN?

As we already emphasized in [3], on the system architecture level, the rescalability is the essential factor. The system should allow easy customer installation of CPEs and it should be easily expanded. Secondly, no single network topology is suitable for all the deployment scenarios of the presumed customers. Thus the WirelessHUMAN system should enable flexible topologies and should not be limited to one fixed solution. Neither of the WLAN systems can fulfil all these requirements and provide all the features as such. There is a need for a new system specification.

It doesn't however mean that there were no functionalities that could be adopted for WirelessHUMAN air-interface standard. For the target markets and applications of the WirelessHUMAN systems TDMA is more applicable than CSMA/CA. There should be a centralized controller in the system and TDMA is a natural selection for that kind of systems. It does provide easier QoS provisioning and better spectrum efficiency than contention based protocols. Thus the HIPERLAN/2 could be used as the baseline for the channel access scheme: TDMA with centralized control and channel allocation information in the beginning of the MAC frame.

Even if the HIPERLAN/2 is based on TDMA, its 2 ms frame and 54 byte cells are not applicable for BFWA system. There is no need for such a short frame and from the network capacity perspective the frame should be around 10 ms. With that frame length it would still be possible to meet even the stringent delay requirements of voice services. The WirelessHUMAN system should also be based on packet delivery and for that 2 ms frame is slightly too short and would result in waste of capacity.

## 4 WLAN PHY for the WirelessHUMAN?

### 4.1 Multi-carrier vs. Single-carrier PHY

Before evaluating the WLAN PHY's for applicability to WirelessHUMAN, a comparison between multi- and single-carrier modulations must be made.

For the target markets (single residents through SME's), cost (and possibility) of engineering LOS links are too high. To enable the market, the installation must be cheap. NLOS operation allows for easy installation, as no careful aiming of antennas or detailed site-review needs to be performed.

OFDM is inherently robust in adverse channel conditions and allows NLOS operation while maintaining a high level of spectral efficiency. It effectively mitigates performance degradations due to multipath. It is capable of combating deep fades in part of the spectrum. The OFDM waveform can be easily modified to adjust to the delay spread of the channel.

Single carrier systems do not inherently have this property, but can be outfitted with an equalizer to achieve a similar effect. However, the complexity of this equalizer would have to be very high to combat channel behavior typical for the targeted band, resulting in undesirable higher cost.

OFDM also allows efficient operation in both FDD and TDD mode as very short or no pre-ambles are needed. There is no need to load channel co-efficients, which requires knowledge of the transmitter and hence mandates polling or scheduling.

### 4.2 WLAN PHY as such?

Although the WLAN PHY has been designed primarily for indoor or short-range outdoor use, it can be used as the baseline of the WirelessHUMAN PHY. All the very basic decisions like number of sub-carriers, channel coding scheme and sub-carrier modulation should be verified after the system performance requirements has been agreed upon. Basically there shouldn't be any absolute necessity to modify the basic parameters. One of the major questions naturally concerns the number of sub-carriers. It is obvious that a higher number of sub-carriers would result in somewhat better interference resilience and a possibility to extend the guard interval. But we must not forget all the implications this kind of change would have: higher PAPR, tighter requirements on phase noise and frequency synchronization, etc.

Whatever will be proposed to be changed in the PHY both the 20 MHz channel raster and the spectrum mask should be adopted without any modifications. First, that would enable more efficient and practical channel allocation and a real co-existence with WLAN devices could really come true. Second, having a similar spectrum mask and basic radio parameters may be the only way to have band for WirelessHUMAN devices in some regulatory areas.

## References

[1] TR 101 683, Broadband Radio Access Networks (BRAN); High PErformance Radio Local Area Networks (HIPERLAN); Type 2; System Overview
[2] IEEE Std 802.11-1999, IEEE standard for Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications
[3] IEEE802.16hc-00/01, Requirements for WirelessHUMAN Systems