

# System Performance of HiperLAN/2

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**Abstract.** Standards for broadband wireless multimedia communications in the 5 GHz band have been developed in Europe as well as in the US and Japan. HiperLAN/2 is a radio based local area networking solution that is intended for connecting mobile users with the backbone network wirelessly. HiperLAN/2 is being developed by ETSI (European Telecommunications Standards Institute). This paper will present HiperLAN/2's system design and performance. Furthermore, comparison is made with the American standard the IEEE 802.11(a).

## 1 Introduction

Wireless technology have enjoyed an increase demand from the general public as well as from business and other professional users, these range from cellular phones to high-speed digital networks supporting high speed computer communications.

HiperLAN/2 (H/2) is an upcoming standard, which is being specified by the ETSI/BRAN project. High Performance Radio Local Area Network type 2 (HiperLAN/2) is one of the wireless broadband access networks, shall provide high-speed communications between mobile terminals and various broadband infrastructure networks. HiperLAN/2 system operates at the 5GHz region. The frequency allocation in Europe is: 5.15-5.35 GHz, lower band (indoor use only) and 5.47-5.725 GHz, upper band (indoor and outdoor use). HiperLAN/2 can be used as an alternative access technology to a 2nd and 3rd generation cellular network. One may think of the possibility to cover hot spots (airport, hotels, etc.) and city areas with HiperLAN/2 and the wide area with GSM and WCDMA technologies. In this way, a user can benefit from a high performance network wherever it is feasible to deploy HiperLAN/2 and use GSM, WCDMA elsewhere. One of advantages of HiperLAN2 is that it could be connected to any backbone network, ATM, IP, Ethernet etc. HiperLAN/2 system is likely to be deployed in a wide range of environments, such as buildings, exhibition halls, airport, industrial buildings and outdoor deployment.

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## 2 High Speed Transmission

One of the main features in HiperLAN/2 system is the high transmission rate that could get up to 54 Mbps [1]. Orthogonal Frequency Division Multiplexing (OFDM) is a type of multicarrier modulation which uses overlapped orthogonal signals to divide a frequency-selective channel into a number of narrow-band flat-fading channels. Instead of transmitting the data symbols sequentially at a high symbol rate on a single carrier, a block of symbols is encoded using the Fast Fourier Transform (FFT), and transmitted in parallel over a number of subchannels.

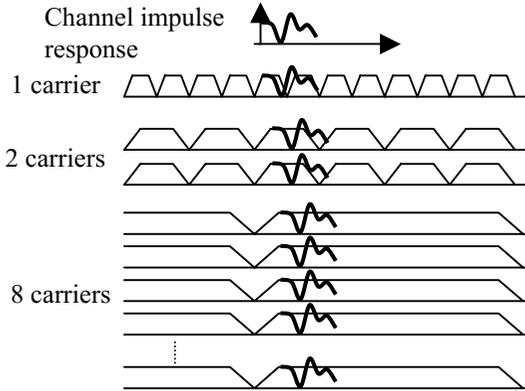


Fig.1. The advantage of multicarrier transmission

The sub-carriers are spaced by the inverse of the symbol period, so making them orthogonal. Individual sub-channels will have a symbol period longer than the multipath delay spread, therefore OFDM is useful for avoiding multipath interference. If a particular sub-channel has high noise then it can be de-activated, hence reducing the effects of fading and interference.

By increasing the number of transmitted carriers the data carried on each carrier reduces and hence the symbol period increases. This means that the Intersymbol Interference (ISI) affects a smaller percentage of each symbol as the number of carriers increase and hence the symbol period increases.

The sub-carriers are said to be orthogonal if

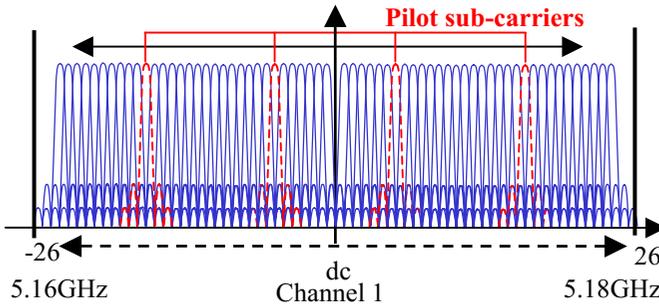
$$\frac{1}{t} \int_0^t e^{j\omega m_1 t} * e^{-j\omega m_2 t} dt = \begin{cases} 1 & \text{if } m_1 = m_2 \\ 0 & \text{else} \end{cases}$$

where  $t$  is the useful symbol period,  $m_1$  and  $m_2$  are subcarrier number. Orthogonality is achieved by using a symbol period equal to subcarrier spacing ( $\approx 1/312\text{kHz}$ ).

### 3 Physical Layer

The transmission format on the physical layer is a burst, which consists of a preamble part and a data part. There are 19 channels in Europe, 9 channels for indoor and 10 channels for indoor and outdoor. Each channel is 20 MHz wide. Total subcarriers are 64 per channel, reflecting on the 64-point IFFT used at the transmitter end of HiperLAN/2 system. 52 subcarriers are used per channel, of which 48 are used for data transmission and 4 for pilot in order to estimate the fading channel.

Each channel, 20MHz wide, is divided into 52 sub-carriers, about 300Khz wide each



**Fig.2.** Sub-carrier allocation in each channel

The sub-carriers are number spread from  $\tilde{n}26$  to 26 (Total of 52 Subcarriers), subcarrier number zero is dc meaning no data will be transmitted on it. Pilot subcarriers are numbered  $\pm 7$  and  $\pm 21$ , as shown in figure 2. All 52 subcarriers are transmitted in one OFDM symbol, the duration of each symbol is  $4\mu\text{sec}$ . This OFDM symbol consists of two parts, the cyclic prefix part (800 nsec) and the useful data part ( $3.2\mu\text{sec}$ ). The length of the useful symbol part is equal to 64 samples.

The cyclic prefix is a cyclic extension of the useful part and it is inserted before the useful part. The cyclic extension is a copy of the last 16 samples of the useful part. The reasons behind using a cyclic are to maintain receiver carrier synchronization and to model the transmission channel by convolving between the OFDM signal and channel response.

The air interface of HiperLAN/2 is based on time division duplex and dynamic time division multiple access, which allows for simultaneous communication in both uplink and downlink within the same time frame called MAC frame. The duration of the MAC frame is 2ms and comprises transport channels for broadcast control (BCH), frame control (FCH), access control (ACH), downlink (DL) and uplink (UL) data transmission and Random access (RCH).

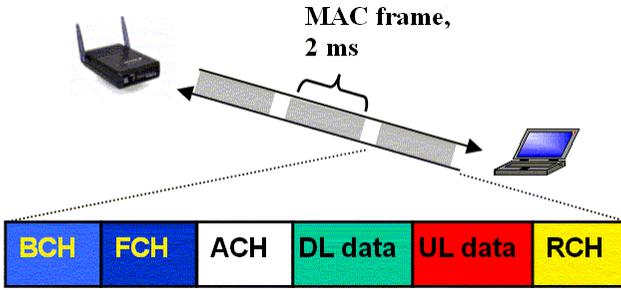


Fig.3. MAC frame structure

In order to improve the link capability due to different interference situations and distances of terminals to the access point (AP), a link adaptation scheme is applied [2], by using various modulation schemes on the subcarriers and puncturing of convolutional codes, the data rate can be varied.

Seven physical layer modes are specified [3], of which the first six are compulsory, where as the last which uses 64 QAM is optional.

Table 1. Physical layer modes of HiperLAN/2

Mo	Modulation	Code	Bit	Bytes/sym
1	BPSK	1/2	6Mbps	3.0
2	BPSK	3/4	9Mbps	4.5
3	QPSK	1/2	12Mbps	6.0
4	QPSK	3/4	18Mbps	9.0
5	16QAM	9/16	27Mbps	13.5
6	16QAM	3/4	36Mbps	18.0
7	64QAM	3/4	54Mbps	27.0

Forward error control is performed by a convolutional code of rate 1/2 and constraint length seven. Code rates 3/4 and 9/16 are obtained by puncturing. The puncturing codes for code rate 3/4 and 9/16 are 11111110111101111 and 110101 respectively.

#### 4 Transport Channels

The broadcast channel (BCH), 15bytes long, contains control information that is sent in every MAC frame and reaches all mobile terminal (MT). Information such as the power levels, starting point and length of the FCH and RCH, network and AP ID.

The frame control channel, multiple of 27 bytes frames depending on the number of MT requests of resources, contains the exact description on the allocated bandwidth, in DL and UL, for the requested users in current MAC frame.

Access feedback channel, 9 bytes long, conveys information on previous access attempts made in the RCH.

All the above channels are transmitted in downlink only (AP to MT).

Uplink and Downlink traffic, bi-directional, consists of Protocol Data Unit (PDU) trains to and from MTs. A PDU train consists of DLC user PDUs (U-PDU of 54 bytes with 48 bytes of payload) and DLC control PDUs (C-PDUs of 9 bytes) to be transmitted or received by one MT. The C-PDUs and data PDUs are referred to as short and long transport channel respectively.

The random access channel, uplink only and it is 9 bytes long. Used by the MTs to gain bandwidth from the AP in the next MAC frame so data could be transmitted.

## 5 Convergence with other Systems

HiperLAN/2 system will be used in Airports, Large shopping malls, Train stations, etc, in order to connect the mobile user with the core network wirelessly. The core network could be Ethernet, ATM, IP or UMTS, i.e. HiperLAN/2 will be used with variety of services and protocols. This is possible due to the flexible architecture that defines a convergence layer (CL) between the core networks and the data link control (DLC) layer [4]. The CL adapts the Higher Layer Protocol to the DLC layer.

Data units that are transmitted within these protocols may differ in length. The CL in HiperLAN/2 segments and reassembles (SAR) these data units (U-PDUs) with fixed length 48 bytes, which are then passed down to DLC and physical layer.

The number of OFDM symbols varies depending on the mode chosen, the higher the mode the fewer number of OFDM symbols required in order to transmit a Long or Short transport channels.

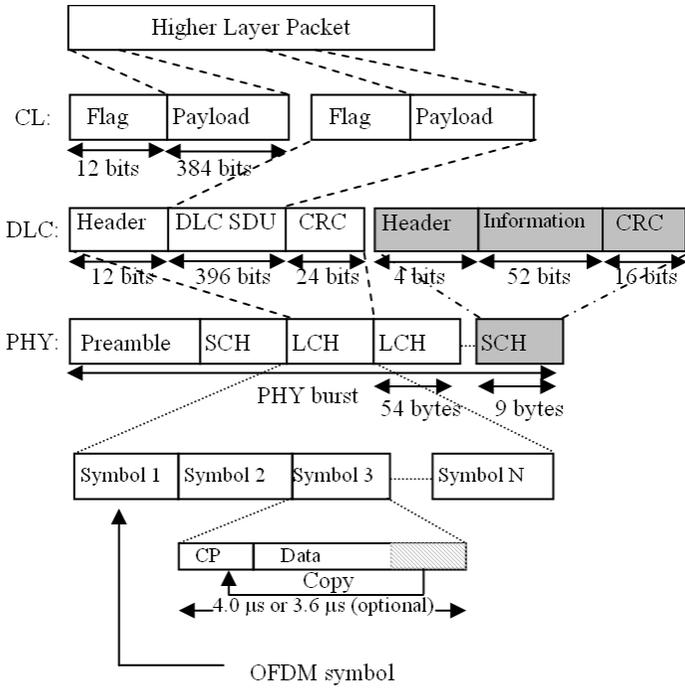
If mode 1 was chosen, i.e. 3 bytes per OFDM symbol, the number of symbols required in order to transmit a 54 byte data PDU is 18 symbols, if mode 4 was chosen then the required number of symbols is 6 per U-PDU.

All modes could be used to transmit the U-PDUs, but only modes 1, 2 and 4 are used to transmit C-PDUs. The U-PDU size is fixed, 54bytes, then for all modes, the  $i$  bytes per OFDM symbol $\hat{i}$  will go into 54 bytes.

In case of C-PDUs where the PDU size is 9 bytes, modes 3, 5, 6 and 7 have  $i$  bytes per OFDM symbol $\hat{i}$  sizes that will not go into the C-PDU. U-PDUs which are detected to be in error after the convolutional decoding are automatically requested for a retransmission (ARQ).

Two different codes are defined in HiperLAN/2 [5]: U-PDUs are protected by the CRC-24 with generator polynomial  $g(x) = x^{24} + x^{10} + x^9 + x^6 + x^4 + x^3 + x + 1$  C-PDUs are protected by the CRC-16 with generator polynomial  $g(x) = x^{16} + x^{12} + x^8 + x^7 + x^6 + x^3 + x + 1$ . The minimum hamming distance for both codes is 6, which is the highest achievable at each case [6].

Using the cyclic redundancy check (CRC) would dramatically reduce PDU error probability.



**Fig.4.** The transformation from data units from upper layer to OFDM symbol in HiperLAN/2 physical layer

## 6 Radio Network Functions

In order to support a number of radio network functions HiperLAN/2 standard defines measurements and signalling. These radio network functions are link adaptation, dynamic frequency selection, power control, multi-beam antenna and handover. All algorithms are vendors specific.

### 6.1 Dynamic Frequency Selection

HiperLAN/2 is a time-division duplex (TDD) system where the interference between the downlink and uplink can never be avoided. The Dynamic Frequency Selection (DFS) allows several operators to share the available spectrum. The DFS has to provide a good frequency plan already shortly after the installation of a new H/2 system. For fairness, the frequency plan established by the DFS should aim in providing individual cell with the same radio quality. A quick reaction due to sudden fades in the link is not desirable in order to avoid frequency reselections. The frequency reselection rate indicates the stability of the system and therefore it is preferable to be kept as low as possible. The task of DFS is to select a single carrier for each cell to ensure a reliable communication with small tolerable interference from other cells. Each access point has been allocated a number of frequencies, for example

$F_1, F_7, F_{13}$ . From time to time the access point orders the mobile terminal to measure the radio signals received from the neighbouring access points. The MT will then report the measurements to the AP on each measured frequency. If the neighbouring AP uses a frequency near the frequency that the current AP is using then this will cause high interference to the MT. The AP will provide the MT with all the frequencies that it has been allocated and asks the MT to take interference measurements for each one with the neighbouring APs. The AP will choose the frequency that has the lowest interference level compared to other frequencies, as reported by the MT, and uses it for later transmissions. The respective protocols [7] specify that the AP controls the measurement period, the frequency on which to measure, the MTs which are requested to measure. Current quality  $q(f)$  of the frequency  $f$  is [8]:

$$q(f) = -(R(f)_{UL} + \bar{R}(f)_{DL}) \div 2 \quad (1)$$

where  $\bar{R}(f)_{DL}$  is the mean value over all values  $R(f)_{DL}$  calculated for each MT having reported its measurement.  $R(f)_{UL}$  is signal measurement measured in AP in the uplink. These quality values  $q(f)$  are filtered (using first order recursive filter with filter renewal coefficient  $C = 0.1$ ) then frequency  $f$  becomes the long term mean quality measures  $Q(f)$ . The current frequency  $f_0$  is kept when  $Q(f) < Q(f_0) + M$  for all frequencies. Where  $M = 1\text{dB}$ , which is the margin if  $Q(f)$  has exceeded  $Q(f_0)$  by then carrier frequency  $f$  will be used rather than  $f_0$ . During these measurements, the AP will stop any data transmission to the MT. The data will be saved and will not be forwarded until the measurements are completed.

## 6.2 Power Control

Power control is needed in order to reduce the interference between HiperLAN/2 system and satellite system. It also reduces the complexity of the AP, for example by not needing to have an Automatic Gain Control (AGC). The transmit power  $P_{MT}$  of each MT is separately controlled within the range  $-15\text{dBm} \leq P_{MT} \leq 30\text{dBm}$ . The minimum acceptable received signal strength at the AP is  $\bar{n}71\text{ dBm}$ . The AP transmits power ranges from  $-15\text{dBm} \leq P_{MT} \leq 30\text{dBm}$ . But the AP requires more accuracy.

## 6.3 Link Adaptation

The radio quality is totally dependent on the radio environment. As the environment gets worst, traffic in surrounding cells increases for example, the carrier to interference ratio (C/I) degrades. The link adaptation scheme adapts the physical robustness based on link quality measurements. Thus the physical mode is dynamically selected for the SCH and LCH in each transmitted MAC frame.

It is performed in both directions, in downlink and uplink in order to minimise the usage of an interfered carrier. In uplink, the AP measures the signal quality and

informs the MT which mode to use in next transmission. In the opposite side, the MT measures the signal received from the AP and then informs the AP on the type of mode to use for the downlink transmissions. However, it is at the AP where the final decision is made, it decides which mode to use for downlink and uplink transmissions.

#### 6.4 Multi-beam Antenna

In order to improve the link budget and improve the carrier to interference ratio (C/I) HiperLAN/2 system employs multi-beam antenna. The MAC protocol and the frame structure in HiperLAN/2 allow up to seven beams to be used. The MT informs the AP on which beam it will receive information from, i.e. it is MT initiated. The selection is based on constant monitoring the link performance, by measurements on the broadcast fields transmitted by each beam.

#### 6.5 Handover

The mobility of the mobile user causes the variation in the link quality and in the interference levels. As the interference level increases the noise level increases.

When such effect occurs the best solution is to allow the Mobile Terminal (MT) to change the AP that it is currently connected with to other AP that provides better S/N ratio. This process is called Handover. Handover is a process used in order to recover the signal quality and to reduce the noise level. It is Mobile Terminal (MT) initiated, i.e. the MT performs the measurements and informs the Access Point for a handover process.

There are three types of Handover in HiperLAN/2 system.

Sector handover (Inter-Sector). During the Sector Handover only the antenna sector of the AP shall be changed.

Radio handover (Inter-APT/Intra-AP Handover). During the Radio Handover the MT changes the transceiver it is currently connected to, to other transceiver at the same AP.

Network handover (Inter-AP/Intra-Network Handover). As the MT moves from one AP coverage area to another it will request Handover to the new AP.

The MT uses the AP with the best radio signal as measured by the signal to noise ratio. As the MT moves around towards the boundary of the associated AP's coverage area, it may detect that there is an alternative AP with better radio transmission performance than the AP that it is currently connected/associated to.

The MT will then order a handover to the new AP. All connections will be moved to this new AP resulting in the MT staying associated to the HiperLAN/2 network and can still continue its communication.

## 7 System Performance

During the standardization process, exhaustive simulations have been conducted for selecting the parameters and performance analysis. Channel models have been developed for standardization. They were derived from measurements in typical indoor and outdoor environments [9].

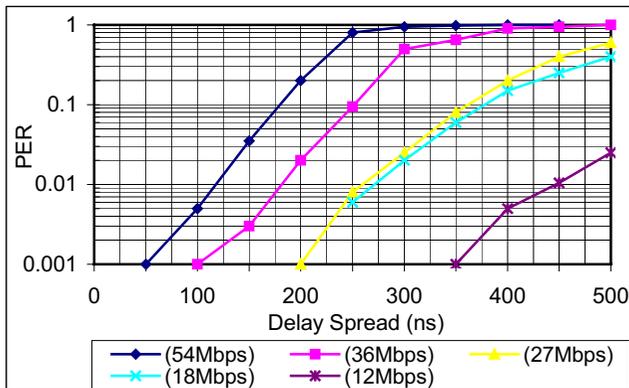
**Table 2.** Channel models for HiperLAN/2

Channel model	r.m.s delay spread	Rice factor on first tap	Environment
A	50 ns	-	Office NLOS (no light of sight)
B	100 ns	-	Open space / Office NLOS
C	150 ns	-	Large open space NLOS
D	140 ns	10dB	Large open space LOS
E	250 ns	-	Large open space NLOS

Figure 5 shows the irreducible PER versus delay spread for few data rates. The figure shows the tolerable delay spread from each mode [10]. This is the minimum possible PER for certain delay spread, for which all packet errors are caused by Intersymbol Interference (ISI) due to the path delays exceeding the guard interval time of the OFDM symbol.

It could be concluded that as the bit rate increases the tolerable delay spread reduces. Taking the case when the PER is equal to 1%, the tolerable delay spread for the 54Mbps rate is estimated 120 ns, for the 27 Mbps bit rate the tolerable delay spread is 260 ns and finally for the 12Mbps bit rate the tolerable delay spread is 450 ns, which is the highest tolerable delay spread compared to other modes.

From the results shown in figure 5, it could be said that the 54 Mbps bit rate could be used in office buildings as it could tolerate delay spread of 120 ns, refer to table 2, whereas the 12Mbps rate could be used in indoor and outdoor environments.

**Fig.5.** PER against Delay spread

Error rate performance at the presence of co-channel interference is shown in figure 6 below. The results shown are only applicable for channel model A (50 ns delay spread).

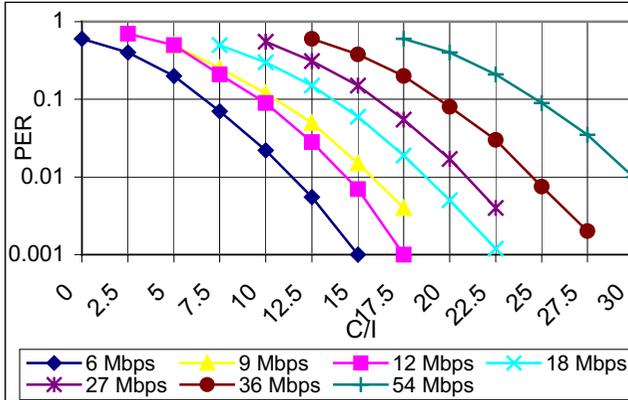


Fig.6. PER against C/I

The performance differences between all modes could be understood from figure 6 above. As the bit rate increases the required C/I for a certain error rate gets higher. Except for mode 2, 9 Mbps, where its performance degrades below mode 3, which is 12 Mbps. This is due to the dominating effect in terms of C/I performance by worst performance of the code rate 3/4 compared to the rate 1/2, i.e. the C/I is dominated by the worst performance from the code rate of 3/4. The respective C/I requirement is between 6.2 dB and 30 dB, as shown in figure 6, depending on the mode, since the reasonable point of operation for packet services may lie between PERs of 1% and 10%. Link adaptation technique is performed by measuring the received signal, and then depending on the calculated C/I the best mode, with the highest throughput, is chosen. Taking for example, at one instant of time the measured C/I from a received signal is 17.5 dBs, hence Mode 6 will be chosen for the next signal transmission. This is one of the main advantages of HiperLAN/2 system, the best mode is always chosen which causes reduction in the interference level.

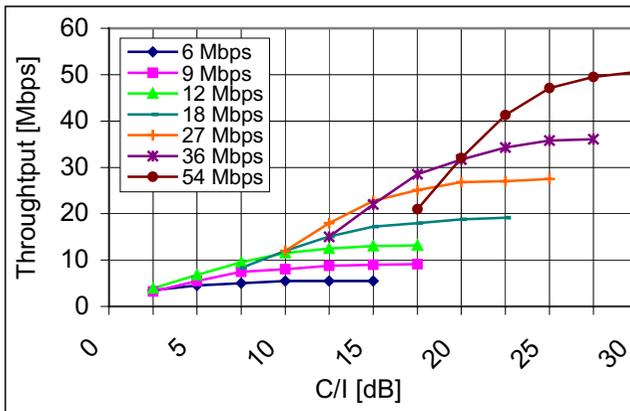


Fig.7. Link throughput against C/I for channel A

## 8 Comparison

In the 5 GHz band, there is another wireless system that is expanding rapidly in US, the IEEE 802.11(a) which will be well harmonized with HiperLAN/2 in physical layer. The upper layers are designed using different concepts.

IEEE 802.11(a) uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) as a channel access technique, where as HiperLAN/2 is based on reservation access which is scheduled by the access point. Both systems use OFDM technology as a modulation technique due to the advantages stated earlier. The physical layer Mode 5 of HiperLAN/2 and IEEE 802.11(a) differ in the rate and hence the code rate used. In IEEE 802.11(a) the fifth mode has a bit rate of 24 Mbps with 16QAM modulation type and 1/2 rate coder. There is an extra mode used in IEEE 802.11(a), where the bit rate is 48 Mbps, the modulation type used is 64QAM and 2/3 coding rate. Both systems throughput were compared and showed that H/2 had better system performance than IEEE 802.11(a). Additional mode supported in IEEE 802.11(a) will help to improve throughput in some scenarios, to reach H/2.

HiperLAN/2 leads 802.11(a) by using Dynamic Frequency Allocation (DFA) technique and Transmit Power Control (TPC) in order to have coexistence with radar systems that operate in the upper part of the European 5GHz band.

## 9 Conclusion

Current wireless communication systems are deployed in every possible spot in order to serve as many users as possible. At the hotspot areas, where the maximum concentration of users are situated current wireless systems still have problems in providing the required coverage area. HiperLAN/2 system will solve these problems. It will mainly be used in these hotspot areas and in office buildings in order to connect the mobile user with the core network wirelessly at high bit rates, which may reach up to 54 Mbps.

The report has shown the physical layer structure of HiperLAN/2. The advantages of using OFDM technique are also been looked at. System's performance under different delay spreads and interference levels also been looked at and shown that the system has good power efficiency technique as HiperLAN/2 has high flexibility in adjusting the link modulation and coding types (hence varying the physical bit rate) that suites the link performance accordingly.

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