HiperLAN/2 – The Broadband Radio Transmission Technology Operating in the 5 GHz Frequency Band

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Version 1.0

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Background

Up until now, wireless networking has been more or less synonymous with wide area cellular networks based on different standards, e.g. GSM, AMPS, etc. They have been defined with the main purpose of supporting voice, though some also offer datacom services at very low speed (~10 kbits/s).

Wireless datacom service offering the throughput necessary to meet the actual requirements for Internet and Intranet access is just on its way to hit the market on a broader scale. In the LAN environment, Wireless LAN (WLAN) products based on the different flavors of 802.11 are available from a range of vendors. Depending on transmission scheme, products may offer bandwidths ranging from about 1 Mbit/s up to 11 Mbit/s. Prices are expected to fall, making WLAN more and more a serious alternative to fixed Ethernet access. In the wide area, General Packet Radio services will most likely be available from the cellular operators year 2000, which will increase the available bandwidth to a user up to about 64 kbit/s, making this datacom service comparable to dial-in.

To meet the networking requirements of tomorrow, a new generation of both WLAN and cellular network technologies are under development. These requirements include support for QoS (to build multiservice networks), security, handover when moving between local area and wide areas as well as between corporate and public environments, increased throughput for the ever-demanding need for better performance from both bandwidth-demanding datacom as well as for instance video-streaming applications.

This paper introduces the reader to the next generation of WLAN technology called HiperLAN/2. HiperLAN/2 is a standard being developed by ETSI which can be used world-wide. The standard is planned to be finalized by the end of –99, and available to non-ETSI-members mid-00. **Please note that the contents of this paper reflects that status in standardisation as of September 1999.**

The HiperLAN/2 network

A HiperLAN/2 network typically has a topology as depicted in figure 1 below. The Mobile Terminals (MT) communicate with the Access Points (AP) over an air interface as defined by the HiperLAN/2 standard. There is also a direct mode of communication between two MTs, which is still in its early phase of development and is not further described in this version of the document. The user of the MT may move around freely in the HiperLAN/2 network, which will ensure that the user and the MT get the best possible transmission performance. An MT, after association has been performed (can be viewed as a login), only communicates with one AP in each point in time. The APs see to that the radio network is automatically configured, taking into account changes in radio network topology, i.e. there is no need for manual frequency planning.

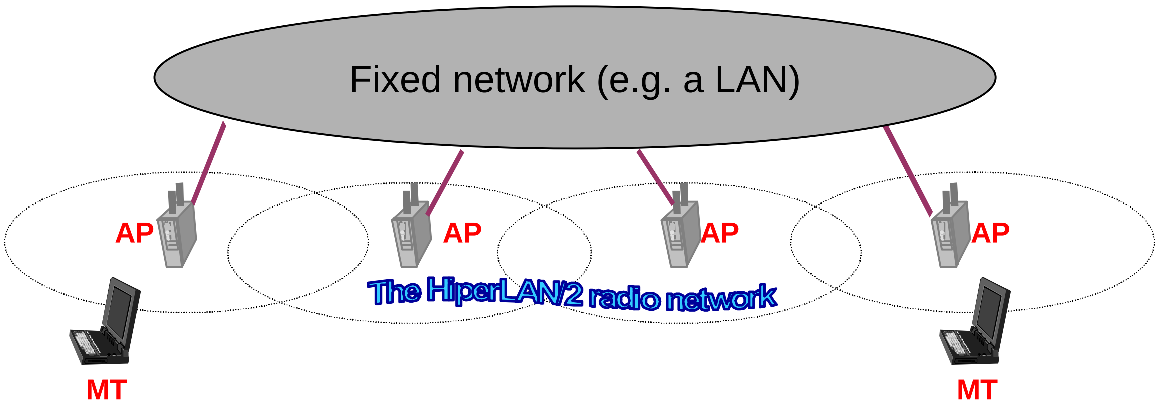


Figure 1: A HiperLAN/2 network.

The features and protocols of the HiperLAN/2 network are further described in the following sections.

Features of HiperLAN/2

The general features of the HiperLAN/2 technology can be summarized in the following list.

- High-speed transmission
- Connection-oriented
- Quality-of-Service (QoS) support
- Automatic frequency allocation
- Security support
- Mobility support
- Network & applicationindependent
- Power save

A short description of each of these features are given below.

High-speed transmission

HiperLAN/2 has a very high transmission rate, which at the physical layer extends up to 54 Mbit/s and on layer 3 up to 25 Mbit/s. To achieve this, HiperLAN/2 makes use of a modularization method called Orthogonal Frequency Digital Multiplexing (OFDM) to transmit the analogue signals. OFDM is very efficient in time-dispersive environments, e.g within offices, where the transmitted radio signals are reflected from many points, leading to different propagation times before they eventually reach the receiver. Above the physical layer, the Medium Access Control (MAC) protocol is all new which implements a form of dynamic time-division duplex to allow for most efficient utlilization of radio resources.

Connection-oriented

In a HiperLAN/2 network, data is transmitted on connections between the MT and the AP that have been established prior to the transmission using signalling functions of the HiperLAN/2 control plane. Connections are time-division-multiplexed over the air interface. There are two types of connections, point-to-point and point-to-multipoint. Point-to-point connections are bidirectional whereas point-to-multipoint are unidirectional in the direction towards the Mobile Terminal. In addition, there is also a dedicated broadcast channel through which traffic reaches all terminals transmitted from one AP.

QoS support

The connection-oriented nature of HiperLAN/2 makes it straightforward to implement support for QoS. Each connection can be assigned a specific QoS, for instance in terms of bandwidth, delay, jitter, bit error rate, etc. It is also possible to use a more simplistic approach, where each connection can be assigned a priority level relative to other connections.
This QoS support in combination with the high transmission rate facilitates the simultanous transmission of many different types of data streams, e.g. video, voice, and data.

Automatic frequency allocation

In a HiperLAN/2 network, there is no need for manual frequency planning as in cellular networks like GSM. The radio base stations, which are called Access Points in HiperLAN/2, have a built-in support for automatically selecting an appropriate radio channel for transmission within each AP’s coverage area. An AP listens to neighboring APs as well as to other radio sources in the environment, and selects an appropriate radio channel based on both what radio channels are already in use by those other APs and to minimize interference with the environment.

Security support

The HiperLAN/2 network has support for both authentication and encryption. With authentication both the AP and the MT can authenticate each other to ensure authorized access to the network (from the AP's point of view) or to ensure access to a valid network operator (from the MT's point of view). Authentication relies on the existence of a supporting function, such as a directory service, but which is outside the scope of HiperLAN/2.

The user traffic on established connections can be encrypted to protect against for instance eaves-dropping and man-in-middle attacks.

Mobility support

The MT will see to that it transmits and receives data to/from the "nearest" AP, or more correctly speaking the MT uses the AP with the best radio signal as measured by the signal to noise ratio. Thus, as the user and the MT move around, the MT may detect that there is an alternative AP with better radio transmission performance than the AP which the MT is currently associated to. The MT will then order a hand over to this AP. All established connections will be moved to this new AP resulting in that the MT stays associated to the HiperLAN/2 network and can continue its communication. During handover, some packet loss may occur.

If an MT moves out of radio coverage for a certain time, the MT may loose its association to the HiperLAN/2 network resulting in the release of all connections.

Network & applicationindependent

The HiperLAN/2 protocol stack has a flexible architecture for easy adaptation and integration with a variety of fixed networks. A HiperLAN/2 network can for instance be used as the "last hop" wireless segment of a switched Ethernet, but it may also be used in other configurations, e.g. as an access betwork to 3rd generation cellular networks. All applications which today run over a fixed infrastructure can also run over a HiperLAN/2 network.

Power save

In HiperLAN/2, the mechanism to allow for an MT to save power is based on MT-initiated negotiation of sleep periods. The MT may at any time request the AP to enter a low power state (specific per MT), and requests for a specific sleep period. At the expiration of the negotiated sleep period, the MT searches for the presence of any wake up indication from the AP. In the absence of the wake up indication the MT reverts back to its low power state for the next sleep period, and so forth. An AP will defer any pending data to an MT until the corresponding sleep period expires. Different sleep periods are supported to allow for either short latency requirement or low power requirement.

Protocol architecture & the layers

In figure 2 below, the protocol reference model for the HiperLAN/2 radio interface is depicted. The protocol stack is divided into a control plane part and a user plane part following the semantics of ISDN functional partioning; i.e. user plane includes functions for transmssion of traffic over established connections, and the control plane includes functions for the control of connection establishment, release, and supervision.
The HiperLAN/2 protocol has three basic layers; Physical layer (PHY), Data Link Control layer (DLC), and the Convergence layer (CL). At the moment, there is only control plane functionality defined within DLC.
The PHY, DLC, and the CL are further detailed in the following sections.

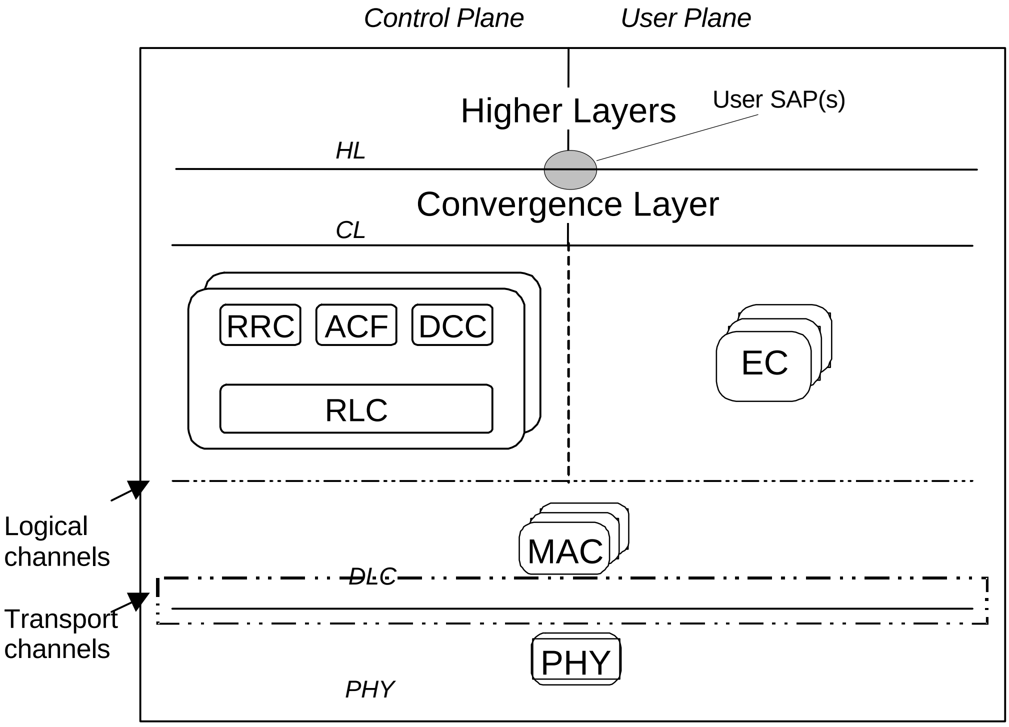


Figure 2, HiperLAN/2 protocol reference model.

Physical Layer [1]

The transmission format on the physical layer is a burst, which consists of a preamble part and a data part, where the latter could originate from each of the transport channels within DLC. Orthogonal Frequency Division Multiplexing (OFDM) has been chosen due to its excellent performance on highly dispersive channels. The channel spacing is 20 MHz, which allows high bit rates per channel but still has a reasonable number of channels in the allocated spectrum (e.g. 19 channels in Europe). 52 subcarriers are used per channel, where 48 subcarriers carry actual data and 4 subcarriers are pilots which facilitate phase tracking for coherent demodulation. The duration of the guard interval is equal to 800 ns, which is sufficient to enable good performance on channels with delay spread of up to 250 ns. An optional shorter guard interval of 400 ns may be used in small indoor environments.

<u>OFDM in more detail</u>
OFDM, Orthogonal Frequency Division Multiplex, is a special form of multicarrier modulation. The basic idea is to transmit broadband, high data rate information by dividing the data into several interleaved, parallel bit streams, and let each one of these bit streams modulate a separate subcarrier. In this way the channel spectrum is passed into a number of independent non-selective frequency subchannels. These sub channels are used for one transmission link between the AP and the MTs.
OFDM is efficiently realized by the use of effective signal processing, fast-fourier transform, in the transmitter and receiver. This significantly reduces the amount of required hardware compared to earlier FDM-systems.
One of the benefits of OFDM is the robustness against the adverse effects of multipath propagation with respect to intersymbol interference. It is also spectrally efficient because the subcarriers are packed maximally close together. OFDM also admits great flexibility considering the choice of and realization of different modulation alternatives. See below.

ODFM requires a properly designed system. Of special importance is the design of frequency synchronization and power amplifier back-off in the receiver. Also the number of subcarriers has to be chosen in an appropriate way.
So far OFDM has been standardized for several applications. Under the name there is discrete multitone (DMT) which is the world standard for asymmetric digital subscriber lines (ADSL). As an example of a wireless broadcast application, OFDM has been standardized for DAB, the European Digital Audio Broadcasting.

A key feature of the physical layer is to provide several modulation and coding alternatives. This is to both adapt to current radio link quality and to meet the requirements for different physical layer properties as defined for the transport channels within DLC. BPSK, QPSK and 16QAM are the supported subcarrier modulation schemes (64QAM is optional). Forward error control is performed by a convolutional code with rate 1/2 and constraint length seven. The three code rates 1/2, 9/16 and 3/4 are obtained by puncturing. Seven physical layer modes (PHY modes) are specified in table 1.

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

Table 1: PHY modes defined for HiperLAN/2.

Data Link Control Layer

The Data Link Control (DLC) layer constitutes the logical link between an AP and the MTs. The DLC includes functions for both medium access and transmission (user plane) as well as terminal/user and connection handling (controlplane). Thus, the DLC layer consists of a set of sublayers:

- Medium Access Control (MAC) protocol.
- Error Control (EC) protocol
- Radio Link Control (RLC) protocol with the asssociated signalling entities DLC Connection Control (DCC), the Radio Resource Control (RRC) and the Association Control Function (ACF)

MAC protocol

The MAC protocol is the protocol used for access to the medium (the radio link) with the resulting transmission of data onto that medium. The control is centralised to the AP which inform the MTs at which point in time in the MAC frame they are allowed to transmit their data, which adapts according to the request for resources from each of the MTs.

The air interface is based on time-division duplex (TDD) and dynamic time-division multiple access (TDMA). I.e. the time-slotted structure of the medium allows for simultaneous communication in both downlink and uplink within the same time frame, called MAC frame in HiperLAN/2. Time slots for downlink and uplink communication are allocated dynamically depending on the need for transmission resources. The basic MAC frame structure on the air interface has a fixed duration of 2 ms and comprises transport channels for broadcast control, frame control, access control, downlink (DL) and uplink (UL) data transmission and random access (see figure 3). All data from both AP and the MTs is transmitted in dedicated time slots, except for the random access channel where contention for the same time slot is allowed. The duration of broadcast control is fixed whereas the duration of other fields is dynamically adapted to the current traffic situation. The MAC frame and the transport channels form the interface between DLC and the physical layer.

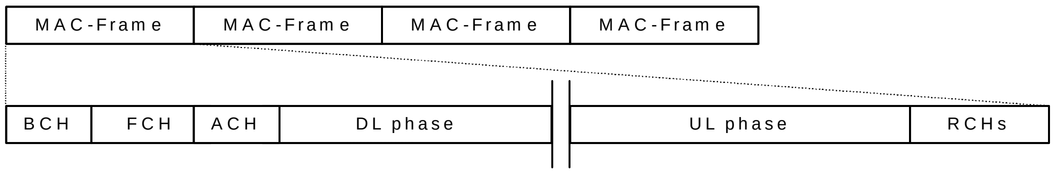


Figure 3: Basic MAC frame structure

Transport channels

The **broadcast channel** (BCH, downlink only) contains control information that is sent in every MAC frame and reaches all the MTs. The BCH provides information (not exhaustive) about transmission power levels, starting point and length of the FCH and the RCH, wake-up indicator, and identifiers for identifying both the HiperLAN/2 network and the AP.

The **frame control channel** (FCH, downlink only) contains an exact description of how resources have been allocated (and thus granted) within the current MAC frame in the DL- and UL-phase and for the RCH.

The **access feedback channel** (ACH, downlink only) conveys information on previous access attempts made in the RCH.

Downlink or uplink traffic (DL- and UL-phase, bidirectional) consits of PDU trains to and from MTs. A PDU train comprises DLC user PDUs (U-PDUs 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. There is one PDU train per MT (if resources have been granted in the FCH). The C-PDUs are referred to as the **short transport channel** (SCH), and the U-PDUs are referred to as the **long transport channel** (LCH).

The **random access channel** (RCH, uplink only) is used by the MTs to request transmission resources for the DL- and UL-phase in upcoming MAC frames, and to convey some RLC signalling messages. When the request for more transmission resources increase from the MTs, the AP will allocate more resources for the RCH. RCH is entirely composed of contention slots which all the MTs associated to the AP compete for. Collisions may occur and the results from RCH access are reported back to the MTs in ACH.

Logical channels

The transport channels (SCH, LCH, and RCH) are used as an underlying resource for the logical channels.

The **slow broadcast channel** (SBCH, downlink only) conveys broadcast control information (and please don't mix up the SBCH with the BCH!) concerning the whole radio cell. The information is only transmitted when necessary, which is determined by the AP. Following information may be sent in the SBCH:

- Broadcast RLC messages
- Conveys an assigned MAC-ID to a none-associated MT
- Handover acknowledgements
- Convergence Layer (higher layer) broadcast information.
- Seed for encryption

All terminals have access to the SBCH. SBCH shall be sent once per MAC frame per antenna element.

The **dedicated control channel** (DCCH, bidirectional) conveys RLC sublayer signals between an MT and the AP. Within the DCCH, the RLC carries messages defined for the DLC connection control and association control functions.
The DCCH forms a logical connection and is established implicitly during association of a terminal without any explicit signalling by using predefined parameters. The DCCH is realized as a DLC connection. Each associated terminal has one DCCH per MAC-ID. This means that when an MT has been allocated its MAC-ID (more details under signalling below) it shall use this connection for control signalling.

The **user data channel** (UDCH, bidirectional) conveys user data (DLC PDU for convergence layer data) between the AP and an MT. The DLC guarantees in sequence delivery of SDUs to the convergence layer. A DLC user connection for the UDCH is setup using signalling over the DCCH. Parameters related to the connection are negotiated during association and connection setup. In the uplink, the MT requests transmission slots for the connection related to UDCH, and then the resource grant is announced in a following FCH. In downlink, the AP can allocate resources for UDCH without the terminal request. ARQ is by default applied to ensure reliable transmission over the UDCH. There may be connections which are not using the ARQ, e.g. connections for multicast traffic.

The **link control channel** (LCCH, bidirectional) conveys information between the error control (EC) functions in the AP the MT for a certain UDCH. The AP determines the needed transmission slots for LCCH in the uplink and the resource grant is announced in an upcoming FCH.

The **association control channel** (ASCH, uplink only) conveys new association request and re-association request messages. These messages can only be sent during handover and by a disassociated MT.

Figure 4 and 5 below show the mapping between logical and transport channels for the downlink and the uplink respectively.

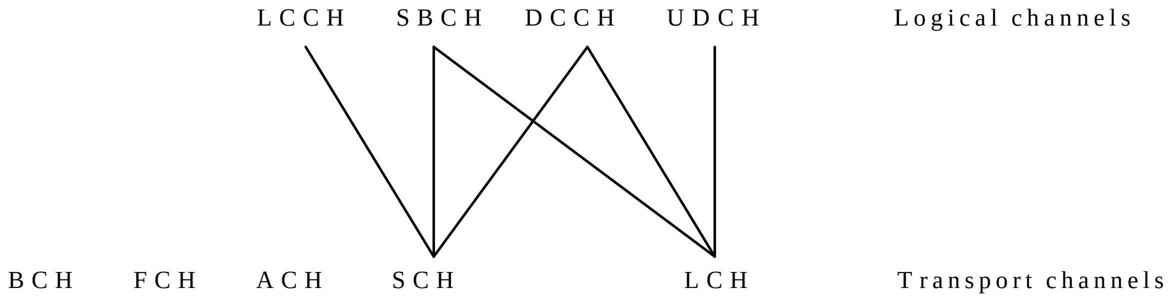


Figure 4: Mapping from logical to transport channels in downlink.

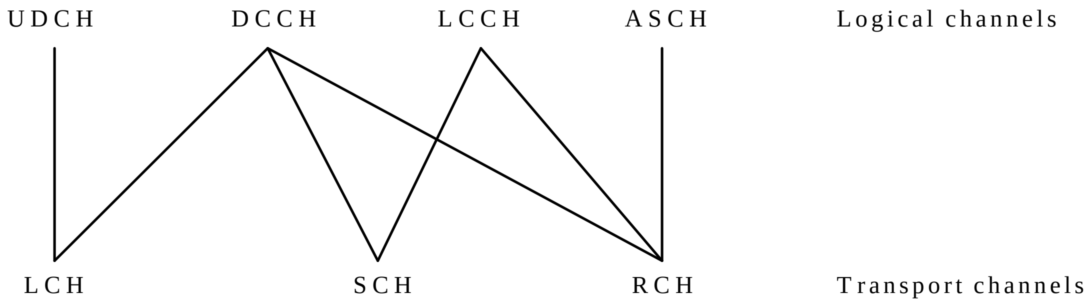


Figure 5: Mapping from logical to transport channels in uplink.

User data transmssion

The connection setup does not result in an immediate capacity assignment by the AP. At the connection setup the MT has received a unique identifier (within the scope of one AP) for each of the established DLC connections. Whenever the MT has data to transmit it initially request capacity by sending a resource request (RR) to the AP. The RR contains the number of pending User Protocol Data Units (U-PDU) that the MT currently has for a particular DLC connection. The MT may use contention slots in the RCH to send the RR message or the SCH. By varying the number of contention slots, the AP could control the actual access delay. Moreover, some contention slots can only be used for high priority traffic which in this context means RR messages. The low priority contention slots are mainly used to initiate handover.
After sending the RR to the AP, the MT goes into a contention free mode where the AP schedules the MT for transmission opportunities as indicated by the resource grant (RG) from the AP. From time to time the AP will poll the MT for more information concerning the MTs current pending PDUs.

Unicast, multicast, broadcast

A DLC connection is used for either unicast, multicast, or broadcast. A connection is uniquely defined by the combination of the MAC identifier and the DLC connection identifier. This combination is also referered to as a DLC user connection (DUC).
For the purpose of transmission of unicast traffic, each MT is allocated a MAC identifier (local significance, per AP) and one or more DLC connection identifiers depending on the number of DUCs.
In case of multicast, HiperLAN/2 defines two different modes of operation; N*unicast and MAC multicast. With N*unicast, the multicast is treated in the same way as unicast transmission in which case ARQ applies. Using MAC multicast, a separate MAC-ID (local significance, per AP) is allocated for each multicast group. ARQ can't be used in this case, i.e. each U-PDU is only transmitted once. All multicast traffic for that group is mapped to the same and one DLC connection. HiperLAN/2 allows for up to 32 multicast groups to be mapped to separate MAC identifiers. In case that the associated MTs like to join more than 32 multicast groups , one of the MAC identifiers will work as an "overflow MAC identifier" meaning that two or more multicast groups may be mapped to that identifier.
Broadcast is also supported. As in the case with multicast, the ARQ doesn't apply, but as the transmssion of broadcast is many times more critical for the overall system performance, a scheme with repetiton of the broadcast U-PDUs have been defined. This means that the same U-PDU is retransmitted a number of times (configurable) within the same MAC-frame, to increase the probablity of a successful transmission. It is worth noticing that reception of braodcast will not change the sleep state of an MT.

The Error Control protocol

Selective repeat (SR) ARQ is the Error Control (EC) mechanism that is used to increase the reliability over the radio link. EC in this context means detection of bit errors, and the resulting retransmission of U-PDU(s) if such errors occur. EC also ensures that the U-PDU's are delivered in-sequence to the convergence layer. The method for controlling this is by giving each transmitted U-PDU a sequence number per connection. The ARQ ACK/NACK messages are signalled in the LCCH. An errored U-PDU can be retransmitted a number of times (configurable).
To support QoS for delaycritical applications such as voice in an efficient manner, a U-PDU discard mechanism is defined. If the data becomes obsolete (e.g. beyond the playback point), the sender entity in the EC protocol can initiate a discard of a U-PDU and all U-PDUs with lower sequence number and which haven't been acknowledged. The result is that the transmission in DLC allows for "holes" (missing data) while retaining the DLC connection active. It is up to higher layers, if there is a need, to recover from missing data.

Signalling and control

The Radio Link Control (RLC) protocol gives a transport service for the signalling entities Accociation Control Function (ACF), Radio Resource Control function (RRC), and the DLC user Connection Control function (DCC). These four entities comprise the DLC control plane for the exchange of signalling messages between the AP and the MT.

Association Control Function (ACF)

Association
It all starts with the MT listening to the BCH from different APs and selects the AP with the best radio link quality. Part of the information provided in the BCH works as a beacon signal in this stage. The MT then continues with listening to the broadcast of a globally unique network operqator id in the SBCH as to avoid association to a network which is not able or allowed to offer services to the user of the MT. If the MT decides to continue the association, the MT will request and be given a MAC-ID from the AP.

This is followed by an exchange of link capabilities using the ASCH starting with the MT providing information about (not exhaustive):

- Supported PHY modes
- Supported Convergence layers
- Supported authentication and encryption procedures & algorithms

The AP will respond with a subset of supported PHY modes, a selected Convergence layer (only one), and a selected authentication and encryption procedure (where one alternative is to not use encryption and/or authentication).

If encryption has been negotiated, the MT will start the Diffie-Hellman key exchange to negotiate the secret session key for all unicast traffic between the MT and the AP. In this way, the following authentication procedure is protected by encryption. HiperLAN/2 supports both the use of the DES and the 3-DES algorithms for strong encryption. Broadcast and multicast traffic can also be protected by encryption through the use of common keys (all MTs associated to the same AP use the same key). Common keys are distributed encrypted through the use of the unicast encryption key. All encryption keys must be periodically refreshed to avoid flaws in the security.
There are two alternatives for authentication; one is to use a pre-shared key and the other is to use a public key. When using a public key, HiperLAN/2 supports a Public Key Infrastructure (PKI, but doesn't define it) by means of generating a digital signature. Authenticaion algorithms supported are MD5, HMAC, and RSA. Also bidrectional authentication is supported for authentication of both the AP and the MT. HiperLAN/2 supports a variety of identifiers for identification of the user and/or the MT, e.g. Network Access Identifier (NAI), IEEE address, and X.509 certificate.

After association, the MT can request for a dedicated control channel (i.e. the DCCH) that it uses to setup radio bearers (within the HiperLAN/2 community, a radio bearer is referred to as a DLC user connection). The MT can request multiple DLC user connections where each connection has a unique support for QoS.

Disassociation
An MT may disassociate explicitly or implicitly. When disassociating explicitly, the MT will notify the AP that it no longer wants to communicate via the HiperLAN/2 network. Implicitly means that the MT has been unreachable for the AP for a certain time period (see more details uner MT alive below). In either case, the AP will release all resources allocated for that MT.

DLC user Connection Control (DCC)
The MT (as well as the AP) requests DLC user connections by transmitting signalling messages over the DCCH. The DCCH controls the resources for one specific MAC entity (identified through the MAC-ID). No traffic in the user plane can be transmitted until there is at least one DLC user connection between the AP and the MT. The signalling is quite simple with a request followed by an acknowledgement if a connection can be established. For each request, the connection characteristics are given. The established connection is identified with a DLC connection identifier, allocated by the AP.

A connection might subsequently be released using a procedure analogue to the establishment. HiperLAN/2 also supports modification of the connection characteristics for an established connection.

Radio Resource Control (RRC)

Handover
The handover starts out from radio link quality measurements (see radio network functions below). This may then result in a request for a handover initiated and requested by the MT. HiperLAN/2 supports two forms of handover; reassociation and handover via the support of signalling across the fixed network.

Reassoication basically means to start over again with an association as described above, which may take some time, especially in relation to ongoing traffic. The other alternative means that the new AP to which the MT has requested a handover to, will retrieve association and connection information from the old AP by transfer of information across the fixed network. The MT provides the new AP with a fixed network address (e.g. an IP address) to enable communication between the old and new AP. This alternative results in a fast handover minimising loss of user plane traffic during the handover phase.

Dynamic frequency selection (DFS)
This is further described below. RRC supports this function by letting the AP have the possibility to instruct the associated MTs to perform measurements on radio signals received from neighboring APs. Due to changes in environment and network topology, RRC also includes signalling for informing associated MTs that the AP will change frequency.

MT alive
The AP supervises inactive MTs which don't transmit any traffic in the uplink by sending an "alive" message to the MT for the MT to respond to. As an alternative, the AP may set a timer for how long an MT may be inactive. If there is no response from the alive messages or alternatively if the timer expires, the MT will be disassociated.

Power save
This function is responsible for entering or leaving low consumption modes and for controlling the power of the transmitter.
This function is MT initiated. After a negotiation on the sleeping time (*N* number of frames where N = 2..216) the MT goes to sleep. After *N* frames there are four possible scenarios:

- The AP wakes-up the MT (cause: e.g. data pending in AP)
- The MT wakes-up (cause: e.g. data pending in MT)
- The AP tells the MT to continue to sleep (again for *N* frames).
- The MT misses the wake-up messages from the AP. It will then execute the MT Alive sequence.

Convergence Layer

The convergence layer (CL) has two main functions: adapting service request from higher layers to the service offered by the DLC and to convert the higher layer packets (SDUs) with variable or possibly fixed size into a fixed size that is used within the DLC. The padding, segmentation and reassembly function of the fixed size DLC SDUs is one key issue that makes it possible to standardize and implement a DLC and PHY that is independent of the fixed network to which the HiperLAN/2 network is connected. The generic architecture of the CL makes HiperLAN/2 suitable as a radio access network for a diversity of fixed networks, e.g. Ethernet, IP, ATM, UMTS, etc.
There are currently two different types of CLs defined; cell-based and packet-based as depicted in figure 6 below. The former is intended for intereconnection to ATM networks, whereas the latter can be used in a variety of configurations depending on fixed network type and how the interworking is specified.

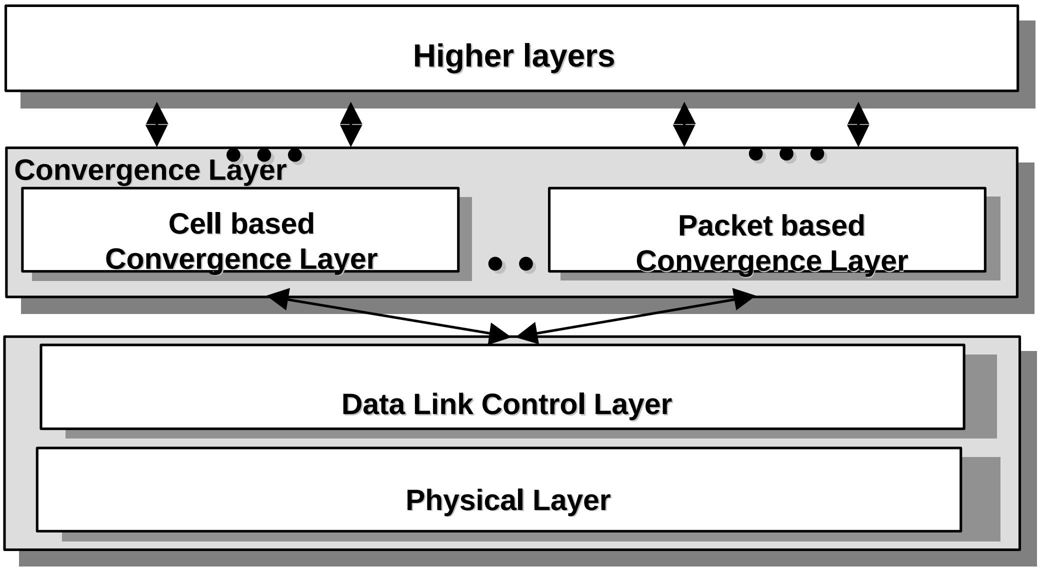


Figure 6: The general structure of the Convergence Layer.

The structure of the packet-based CL with a common and service-specific part allows for easy adaption to different configurations and fixed networks. From the beginning though, the HiperLAN/2 standard specifies the common part and a service specific part for interworking with a fixed ethernet network. The packet-based CL is depicted in figure 7 below.

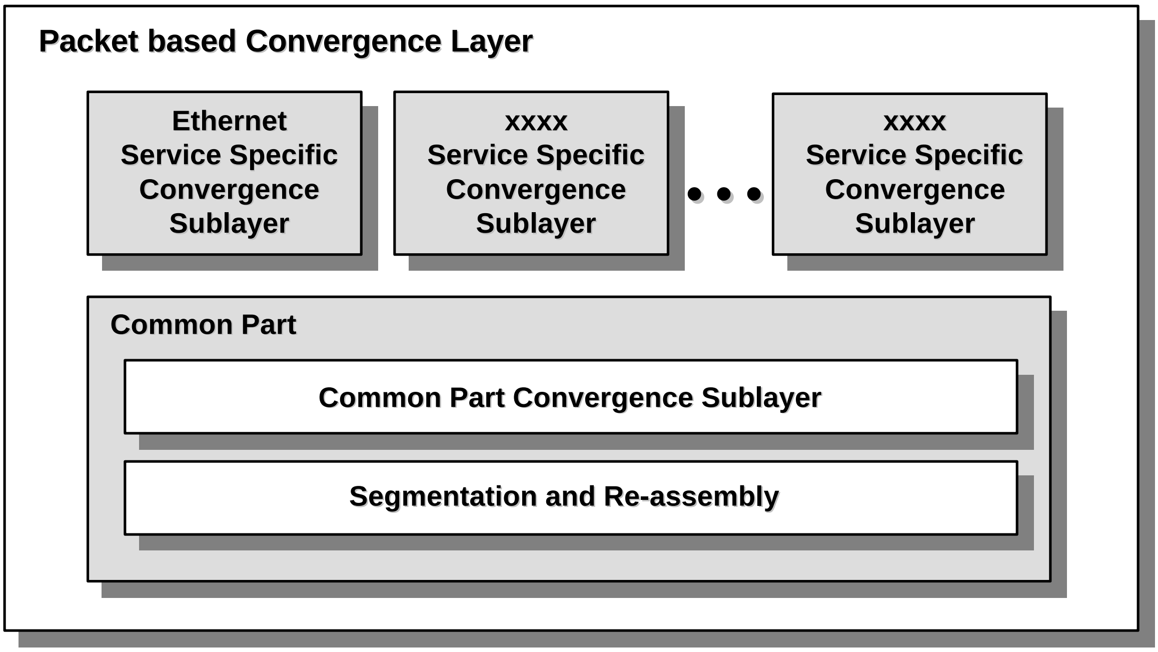


Figure 7: The general structure of the packet-based CL.

Common part

The main function of Common Part of the Convergenec layer is to segment packets received from the SSCS, and to reassemble segmented packets received from the DLC layer before they are handed over to the SSCS. Included in this sublayer is also to add/remove padding octets as needed to make a Common Part PDU being an integral number DLC SDUs.

Ethernet SSCS

The Ethernet SSCS makes the HiperLAN/2 network look like wireless segments of a switched Ethernet. Its main functionality is the preservation of Ethernet frames. Both, IEEE 802.3[1] frames and tagged IEEE802.3ac[2] frames are supported. The Ethernet SSCS offers two Quality of Service schemes: The best effort scheme is mandatory supported and treats all traffic equally. The IEEE 802.1p based priority scheme is optional and separates traffic in different priority queues as described in IEEE 802.1p. As a benefit the DLC can treat the different priority queues in an optimised way for specific traffic types.

Radio network functions

The HiperLAN/2 standard defines measurements and signalling to support a number of radio network functions. These are currently defined as dynamic frequency selection, link adaptation, radio cell handover, multi beam antennas and power control. All algorithms are vendor specific. The following sections outlines the contents of the radio network functions.

Dynamic frequency selection

The HiperLAN/2 radio network shall automatically allocate frequencies to each AP for communication. This is performed by the Dynamic Frequency Selection (DFS) function, which allows several operators to share the available frequency spectrum and can be used to avoid the use of interfered frequencies. The frequency selection made by each AP is based on filtered interference measurements performed by the AP and its associated MTs.

Link adaption

To cope with the varying radio quality, in terms of signal to interference ratio (C/I), a link adaptation scheme is used. The range of C/I levels varies depending on location where the system is deployed and also changes over time depending on the traffic in surrounding radio cells. The link adaptation scheme adapts the PHY robustness based on link quality measurements. Thus, the PHY mode is dynamically selected for the SCH and LCH in each transmitted MAC frame.

Antennas

Multi beam antennas are supported in H/2 as a means to improve the link budget and increase the C/I ratio in the radio network. The MAC protocol and the frame structure in H/2 allow up to 7 beams to be used.

Handover

The handover scheme is MT initiated, i.e. a MT performs the necessary measurements on surrounding APs and selects appropriate APs for communication. The handover measurements are not defined in the standard, i.e. a vendor can chose to base the handover on signal strength or some other quality measurement. The standard defines necessary signaling to perform the handover.

Power control

Transmitter power control is supported in both MT (uplink) and AP (downlink). MT power control is mainly used to simplify the design of the AP receiver, e.g. no AGC is needed. AP power control is part of the standard out from regulatory reasons, i.e. to decrease the interference to satellite systems.

Spectrum allocation & area coverage

In Europe, 455 MHz is suggested to be allocated for Hiperlan systems. The different parts of the bands have different operational conditions set by CEPT to allow co-existence with other services. A draft ERC decision is made and is expected to be approved during autumn -99.

[1] Includes Ethernet Version 2 frames
[2] Includes Ethernet Version 2 tagged frames

In US, 300 MHz is allocated to wireless LANs in the so-called National Information Infrastructure (NII) In Japan, 100 MHz is allocated for Wireless LANs, and more spectrum allocation is under investigation. The ITU-R have also started activities to recommend a global allocation for Wireless LANs.

A cell of a HiperLAN/2 AP typically extends to approximately 30 (office indoor) – 150 meters.

Figure 8 and 9 below shows the current status regarding frequency allocation in USA, Europe, and Japan.

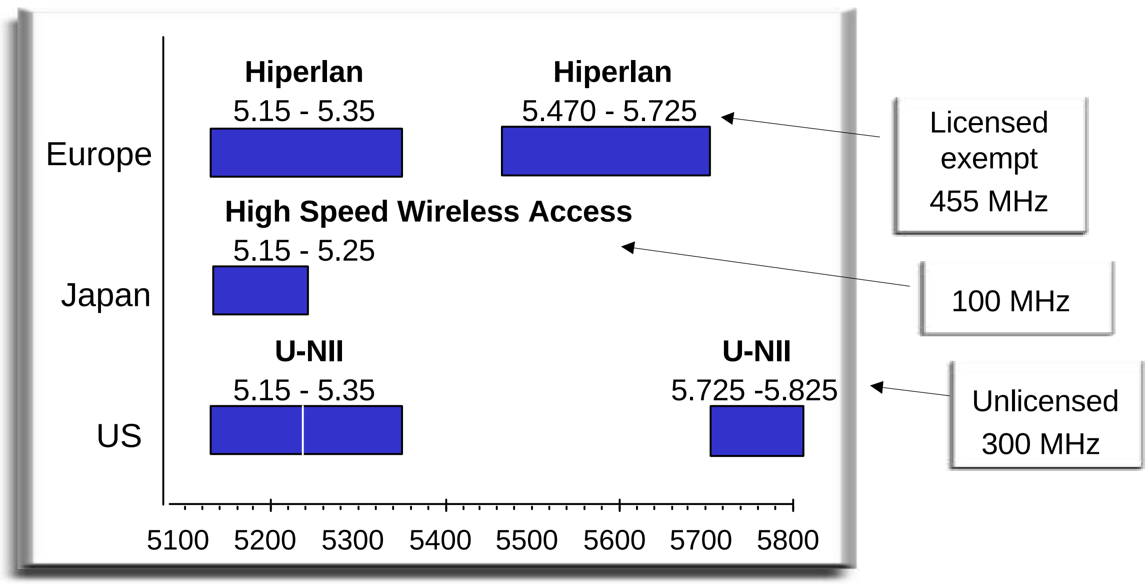


Figure 8: Spectrum allocation in 5 GHz.

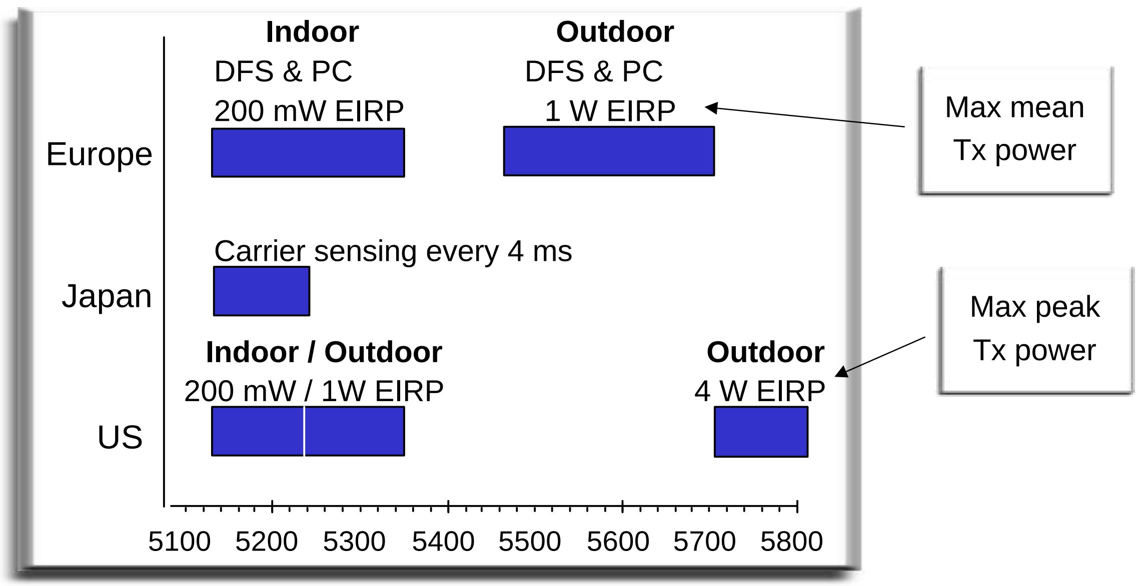


Figure 9: Spectrum rules on 5 GHz.

How it all works

Figure 10 below shows a scenario with an MT, three APs which are connected to a fixed ethernet supporting the Q-tag with priority indications.

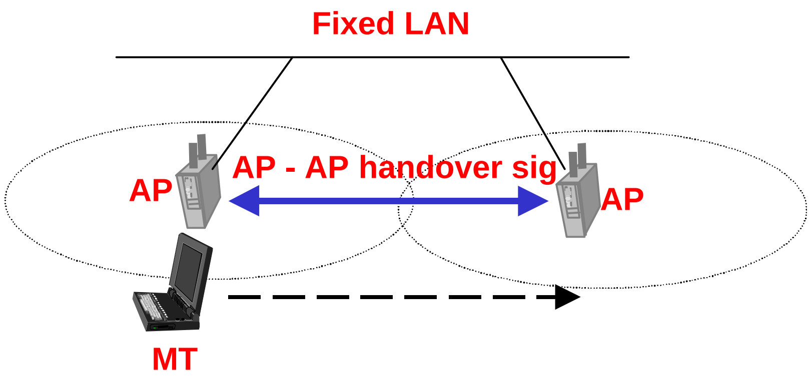


Figure 10: Sample HiperLAN/2 network connected via a fixed LAN.

The APs have each selected appropriate frequencies with the DFS algorithm.

The MT starts by measuring signal strength and select the appropriate AP to which it wants to get associated. From the selected AP the MT receives a MAC-ID. This is followed by exchange of link cabalilities to decide upon, among other things, the authentication procedure to use and encryption algorithm as well as which convergence layer to use for user plane traffic. After a possible key exchange and authentication, the MT is associated to the AP. Finally, the DLC user connections are established over which the user plane traffic is transmitted.

The MT will send and receive data on two established connections (default in HiperLAN/2) supporting two different priority queues onto which the Q-tag priorities are mapped (but more priority queues can be supported). The Ethernet CL enusres that the priorities for each Ethernet frame is mapped to the appropriate DLC user connection according to the predefined mapping scheme

The MT may subsequently decide to join one or more multicast groups. The HiperLAN/2 network may be configured to use N*unicast for optimal quality, or reserve a MAC-ID for each joined group for the sake of conserving bandwidth. If a separate MAC-ID is used for a multicast group, the mapping is:
IP address → IEEE address → MAC-ID

As the MT moves, it may decide to perform a handover if it detects that there is an AP better suited for communication (e.g. with higher signal strength). All established connections as well as possible security associations will be automatically handed over to the new AP using AP – AP signalling via the fixed LAN. When the MT (or more correct the user) wants to get disconnected from the LAN, the MT will ask for disassociation, resulting in the release of all connections between the MT and the AP. This may also be the result if the MT happens to move out from radio coverage for a certain time period.

Example applications

Corporate LAN

Figure 11 below shows an example of a corporate network built around ethernet LAN and IP routers. A HiperLAN/2 network is used as the last segment between the MTs and the network/LAN. The HiperLAN/2 network supports mobility within the same LAN/subnet. Moving between subnets implies IP mobility which must be taken care of on a layer above HiperLAN/2.

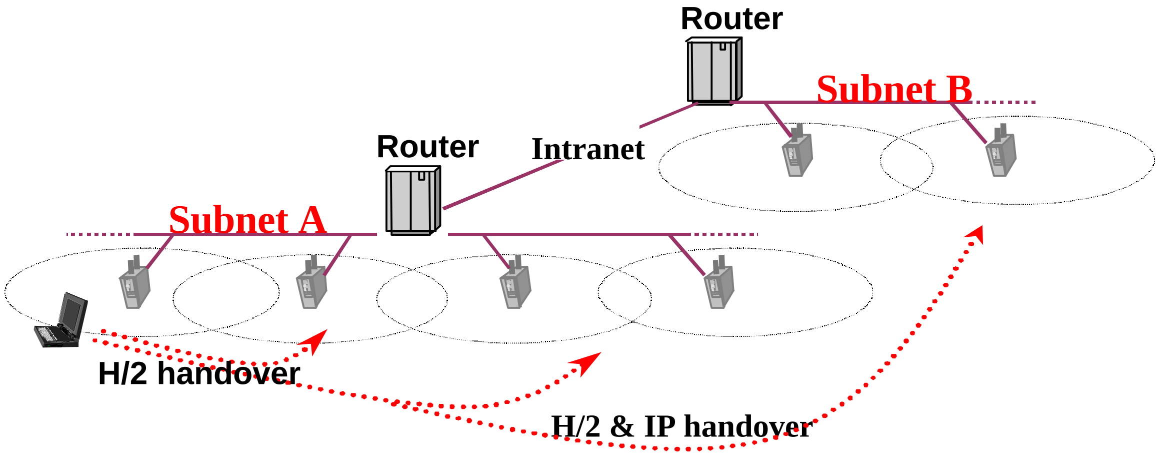


Figure 11: HiperLAN/2 used in a corporate network.

Hot spots

HiperLAN/2 networks can be deployed at hot spot areas, e.g. airports, hotels, etc, to enable an easy way of offering remote access and Internet services to business people. An access server to which the HiperLAN/2 network is connected can route a connection request for a point-to-point connection (PPP) over a tunnel either to to the corporate network (possibly via a preferred ISP) or perhaps to an ISP for Internet access.

Access to 3rd generation cellular network

HiperLAN/2 can be used as an alternative access technology to a 3rd generation cellular network. One may think of the possibility to cover hot spots and city areas with HiperLAN/2 and the wide area with W-CDMA technology. In this way, a user can benefit from a high-performance network wherever it is feasible to deploy HiperLAN/2 and use W-CDMA elsewhere. The core network sees to that the user is automatically and seamlessly handed over between the two types of access networks as the user moves between them.

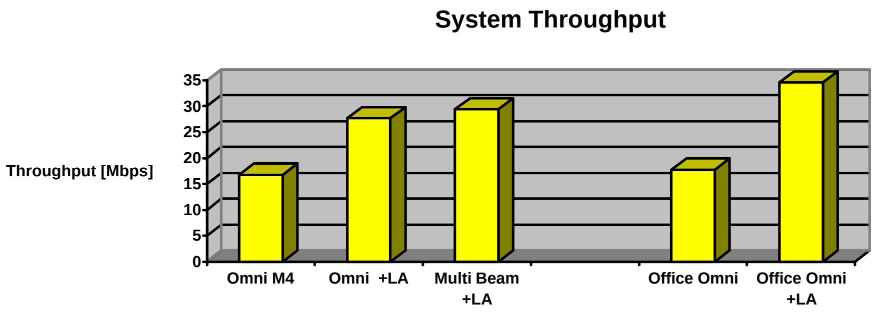
Home network

Another example of HiperLAN/2 is to use the technology in a home environment to create a wireless infrastructure for home devices, e.g. home PCs, VCRs, cameras, printers, etc. The high throughput and QoS features of HiperLAN/2 support the transmission of video streams in conjunction with the datacom applications. The AP may in this case include an “uplink” to the public network, e.g. an ADSL or cable modem.

Performance

The performance in terms of user throughput and delay depends upon a number of factors, such as the available number of frequencies, the propagation conditions in the building and the presence of interference, e.g. another H/2 system in the close vicinity.

The performance for two "typical" environments have been evaluated, a five storey office building and an open exhibition hall [2]. The office building includes attenuation from walls and floors, and the exhibition hall consists only of line of sight propagation. The performance with link adaptation is compared with a reference case with a fixed PHY mode (mode 4. The obtained performance results can be compared to the ETSI requirement of 20 Mbps average system throughput and 25 Mbps peak data rate (input to the physical layer)). The system throughput is calculated as the mean throughput for all users.



In the office environment the reference case with a fixed PHY mode and omni antennas does not provide the required 20 Mbps system throughput. However, when link adaptation is used, the throughput is close to 35 Mbps, i.e. well above the requirement.

In the exhibition hall, the throughput also exeeds the required 20 Mbps when link adaptation is used. It can be seen that the use of multi beam antennas increase the throughput even further. Given that the exhibition hall scenario is an extreme case, e.g. with LOS propagation and 100 % system load, the requirements are expected to be fulfilled for most scenarios and traffic mixes.

Comparision 802.11 V/S HiperLAN/2

Table 2 below summarizes the characteristics of 802.11, 802.11b, 802.11a, and HiperLAN/2.

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 Mbit/s	54 Mb/s	54 Mbit/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
Authentication	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

Table 2: Comparision between 802.11 and HiperLAN/2.

1. Two different modes supported, multicast via a dedicated MAC-ID (same as for 802.11) 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.

References

[1] J. Khun-Jush, P. Schramm, U. Wachsmann, F. Wenger,”Structure and Performance of the HIPERLAN/2 Physical Layer”, VTC'99Fall.

[2] J. Torsner, G. Malmgren, ”Radio Network Solutions for HIPERLAN/2”, Proc. of VTC '99 Spring (Houston).

Acknowledgements

This paper would not have been possible without the explicit contributions and valuable comments from:

Lennart Gåfvels
Henrik Hagnell
Ulf Hansson
Mikael Jonsson
Jan Lindskog
Göran Malmgren
Jan Speich
Johan Torsner

Terminology & Acronyms

Access feedback Channel: A transport channel where the status of access attempts made in the previous MAC frame is conveyed.
Association Control Channel: A logical channel used for passing association information between the AP and the MT.
Association Control Function: A group of control functions on top of the RLC that is responsible for the handling of the association between MT and AP.
Broadcast CHannel: A transport channel that broadcast control information.
Frame CHannel: A transport channel that broadcast control information related to the current frame.
DLC User Connection: all data over the radio interface is carried through DLC connections. The DLC User Connection identifies the addressing (logical channels) and treatment of data transported over the air. A connection carries either user or control messages over the air interface.
DLC User Connection Control: A group of control functions on top of the RLC that is responsible for the handling of DLC user connections.
Error control: The error control is responsible for detection of transmission errors and, where appropriate, for the retransmissions.
Handover: The procedures by which an MT, due to its own movement and/or due to changes in the radio environment not caused by own movement, replaces the current association and all established connections the MT has with one AP to another AP.
Logical channel: A generic term for any distinct data path. A set of logical channel types is defined for different kinds of data transfer service as offered by MAC. Each logical channel type is defined by what type of information is transferred. Logical channels can be considered to operate between logical connection end points.
MAC Frame: A TDMA/TDD frame structure containing a broadcast, downlink uplink and a random access phase.
PDU trains: A sequence of short transport channels and long transport channels.
PHY mode: A PHY mode corresponds to a signal constellation (Modulation alphabet) and a code rate combination.
Random Access CHannel: Logical channel in the uplink of the MAC frame in which the MTs can send signalling data for the DLC user and control plane.
Random Access Phase: The contention period of the MAC Frame where any MT can try to access the system, part of the RCH.
Radio Link Control Protocol: Control protocol that communicates via the C-SAP of the DLC. It is responsible for the transmission of messages that are originated from or addressed to the RRC, ACF and DCC.
Radio Resource Control: A group of control functions on top of the RLC that is responsible for the handling of radio resources.
Roaming: The means by which a collection of networks allow for an MT to get connected/associated and use the services of these networks.
Transport Channel: The physical layer offers information transfer services to MAC and higher layers. The physical layer transport services are described by how and with what characteristics data are transferred over the radio interface.

ACF	Association Control Function
ACH	Access feedback Channel
AGC	Automatic Gain Control
AP	Access Point
ARQ	Automatic Repeat Request
ASCH	ASsociation control CHannel
BCH	Broadcast Channel
CA	Collision Avoidance
CL	Convergence Layer
C-SAP	Control Service Access Point
CSMA	Carrier-Sense Multiple Access
DCCH	Dedicated Control CHannel
DFS	Dynamic Frequency Selection
DLC	Data Link Control
DLCC	DLC Connection
DUC	DLC User Connection
DCC	DLC user Connection Control
EC	Error Control
FCH	Frame CHannel
LCCH	Link Control CHannel
LCH	Long transport CHannel
MAC	Medium Access Control
MAC-ID	MAC identifier
MT	Mobile Terminal
PDU	Protocol Data Unit
PHY	PHYsical layer
RCH	Random CHannel
RLC	Radio Link Control
RRC	Radio Resource Control
SAP	Service Access Point
SBCH	Slow Broadcast CHannel
SCH	Short transport Channel
SDU	Service Data Unit
TDD	Time-Division Duplex
TDMA	Time-Division Multiple Access
U-SAP	User Service Access Point
UDCH	User Data CHannel