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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Radio Equipment and Systems (RES).

Technical Reports are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status.

A Technical Report may be used to publish material which is either of an informative nature, relating to the use or application of European Norms or ETSI standards, or which is immature and not yet suitable for formal adoption as a standard.

The present document describes the requirements and architectures that are applicable to HIgh PErformance Radio Local Area Network (HIPERLAN) Types 2, 3 and 4.

Introduction

Wireless networks have enjoyed an increased demand from the general public as well as from business and other professional users.

Wireless networks in existence today range from cellular phones to high speed digital networks supporting high speed computer communications. They operate in licensed as well as in unlicensed frequency bands.

At the same time, wired telecommunications networks have shown a remarkable evolution towards higher transmission rate and support for multi-media applications rather than simple voice oriented services.

ETSI has recognized the trend towards better and faster wireless networking demands from all kinds of users. Working with the CEPT resulted, in the period 1990 through 1992, in spectrum designations in the 2,4 GHz ISM band, in the 5,2 GHz band and in the 17,1 GHz band to allow the development of a variety of standards for wireless networks. The 2,4 GHz ISM band was intended for medium speed "wide band data systems using spread spectrum techniques". The latter two bands were assigned to HIPERLANs, a collective reference to High Performance Radio Local Area Networks. ETSI has identified the need for a family of HIPERLAN standards that together support a wide variety of usage scenarios and applications.

HIPERLAN Type 1 provides a ISO 8802 [5] compatible wireless local area network;

HIPERLAN Type 2 is intended to provide short range wireless access to Asynchronous Transfer Mode (ATM) networks;

HIPERLAN Type 3 is intended to provide remote wireless access to ATM networks ("high performance local loop");

HIPERLAN Type 4 is intended to provide very high speed point-to-point connections for ATM networks.

HIPERLAN Types 1,2 and 3 are intended to operate in the 5,2 GHz band; Type 4 is intended to operate in the 17,2 GHz band. The CEPT has designated 100 MHz of spectrum in the 5 GHz band for HIPERLANs with a further 50 MHz available at the discretion of national administrations, and 200 MHz in the 17 GHz band. (See CEPT Recommendation T/R 22-06 [1] and ERC Decision 96/03 [6]). Because the current allocation in the 5,2 GHz band is expected not to be sufficient for the projected needs of users and their applications, ETSI has initiated discussions with CEPT aimed at making more spectrum available in this range.

NOTE: The CEPT has also recommended that spectrum in the 40 and 60 GHz bands be exploited by Mobile Broadband Systems (MBS). Although, having a similar architecture to the HIPERLAN family, MBS is severly disadvantaged by the much higher RF frequency, for reasons similar to those discussed in subclause 6.2.

Developments in other types of wireless networks have increased the scope and potential applications of such networks. A primary example is UMTS (or FPLMTS as its known outside Europe). UMTS, in its various forms, supports a wide range communications services, from cordless services to wide area cellular services. The range of bit rates, with a maximum of 2 Mb/s, supported by UMTS is geared primarily towards voice and low quality video as well as data services. However, because of spectrum limitations as well as for economic reasons, UMTS will not be able to meet the bandwidth demands of true, high resolution multi-media communications. These require bit rates in the range of 10 Mb/s. The required bandwidth is not available in the planned UMTS frequency range and it is likely that the cost to users of such bandwidth would be excessive. Furthermore, it is not clear that there exists demand for such high speed services beyond the premises of a business or other organization. On premises, short range wireless networks that do not share spectrum with UMTS are much more attractive and flexible as a solution to multi-media wireless networking. HIPERLANs fill that need. The following figure clarifies the relationship between HIPERLANs and UMTS:

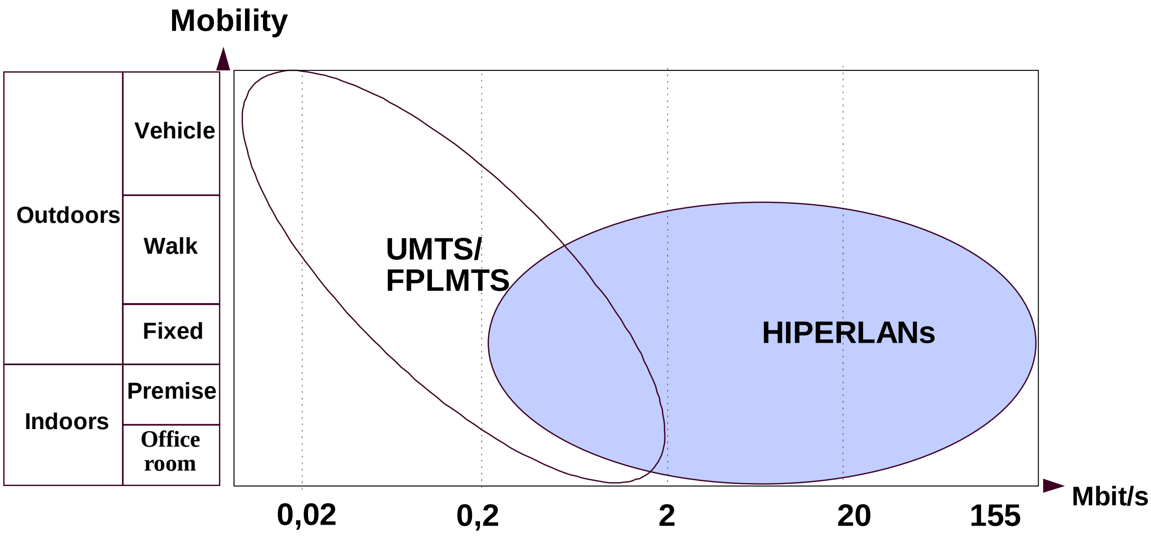

Figure 1: The relationship between HIPERLANs and UMTS/FPLMTS

It should be noted that the above does indicates that users may well perceive benefits form being able to access UMTS based services from HIPERLAN compatible devices and vice versa. That subject is outside the scope of the present document.

To date ETSI has published two standards: ETS 300 328 [3] which provides the type approval requirements for data networks operating in the 2,4 GHz ISM band and ETS 300 652 [2] which provides a functional specification of high speed ISO 8022 compatible wireless networks.

The present document describes the requirements and architectures for HIPERLANs Type 2, 3 and 4. The requirements address subjects like applications, traffic volumes and traffic patterns that underlie the projected spectrum requirements as well as the chosen architectures. The architectures address the communications layer models as well as the Reference models that identify the key interfaces subject to standardization.

The present document has been written to assist the ETSI membership as well as the potential users of standards for high speed wireless data systems in understanding the applications and concepts that underlie the standards for HIPERLANs Types 2, 3 and 4.

As this understanding develops during the writing of the actual standards, the present document is likely to require change. Therefore, it should be treated as a living document rather than a definitive text.

1 Scope

Scope of the present document

The scope of the present document is limited to the requirements and architectures for HIPERLAN Types 2, 3 and 4. HIPERLAN Type1 is addressed by ETS 300 652 [2] and its related Conformance Test Specifications.

The requirements address subjects like applications, traffic volumes and traffic patterns that underlie the projected spectrum requirements as well as the chosen architectures. The architectures address the communications layer models as well as the Reference models that identify the key interfaces subject to standardization.

The architectures developed in the present document are intended to delineate the boundaries between HIPERLAN standards and standards for networks in which HIPERLANs may be used as subsystems or components.

Scope of standardization

The scope of the HIPERLAN standards for HIPERLAN Types 2, 3 and 4 is limited to the air interface specifications, the Data Link Control (DLC) layer specifications and the specifications of the management functions. The DLC layer specification includes a specification of the services to be provided.

HIPERLAN standards specify subsystems up to and including the DLC Layer. The specification of other functions and interfaces required to define a complete system, e.g. the interworking specifications for interworking with higher layer belonging to various network types (e.g. ATM networks, TCP/IP networks, etc.) are outside the scope of HIPERLAN standards. These standards are provided by other bodies, e.g. the ATMForum and the ISO (ISO/IEC JTC1/SC6).

2 References

References may be made to:

a) specific versions of publications (identified by date of publication, edition number, version number, etc.), in which case, subsequent revisions to the referenced document do not apply; or

b) all versions up to and including the identified version (identified by "up to and including" before the version identity); or

c) all versions subsequent to and including the identified version (identified by "onwards" following the version identity); or

d) publications without mention of a specific version, in which case the latest version applies.

A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] CEPT Recommendation T/R 22-06: "Harmonized radio frequency bands for HIPERLAN systems".

[2] ETS 300 652: "High PErformance Radio Local Area Network (HIPERLAN), Type 1 Functional Specification".

[3] ETS 300 328: "Radio Equipment and Systems (RES); Wideband transmission systems; Technical characteristics and test conditions for data transmission equipment operating in the 2 4 GHz ISM band and using spread spectrum modulation techniques".

[4] ITU-T Recommendation Q.2931 (1995): "Digital Subscriber Signalling System No. 2 - User-Network Interface (UNI) layer 3 specification for basic call/connection control". Modified by Rec Q.2971 (1995).

[5] ISO 8802 (1988): "Information processing systems - Local Area Networks".

[6] ERC Decision 96/03: "ERC Decision on the harmonised frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs)".

[8] ATM User-Network Interface Specification V4.0.

[9] ITU-T Recommendation I.356 (1996): "B-ISDN ATM layer cell transfer performance".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following definitions apply:

[local] access: This term is used in the telecommunications sense: short range (< 100 m) wireless access to other, possibly wired, networks.

[remote] access: This terms is used in the telecommunications sense: long range (< 10 km) wireless access to other, possibly wired, networks. Remote access networks are also referred to as "local loop networks".

[wireless] access subnetwork: A [wireless] subnetwork that is a physical subset of an access network. It is serviced by a single [wireless] access point.

[wireless] access network: The combined [wireless] subnetworks providing access to a single external network, e.g. an ATM switch.

[wireless] access point: A device controlling a single [wireless] access subnetwork.

asynchronous traffic: Data traffic that characteristically has a statistical arrival and delay distribution. This typifies most LAN data traffic.

Business Premises Network (BPN): A network covering a privately owned network.

data confidentiality: Provisions for the protection of transmitted data from observation by unauthorized stations or other monitoring means. One measure for doing that is to implement encryption.

Data Link Control (DLC): Layer 2 of the ISO/OSI reference model.

Domestic Premises Network (DPN): A network covering home environment.

downlink: The incoming data direction from a wireless terminal adapter perspective.

encryption: A means of obtaining data confidentiality. See also: Data confidentiality.

handover: The changing of the path over which information flows between two communicating HIPERLAN nodes without being disconnected.

HIPERLAN: HIgh PErformance Radio Local Area Network.

interworking: Interaction between dissimilar sub-networks, end systems, or parts thereof, providing a functional entity capable of supporting end-to-end communications.

Local Area Network (LAN): A group of user stations each of which can communicate with at least one other using a common transmission medium commonly managed.

Logical Link Control (LLC): ISO 8802 [5] layer between the network layer and the MAC layer of the IEEE 802 reference model.

MAC Service Data Unit (MSDU): The fundamental unit of data delivery between MAC entities.
see: Service Data Unit.

Medium Access Control (MAC): The layer of the ISO 8802 [5] reference model between the PHY (see definition) and the LLC (see definition).

Protocol Data Unit (PDU): Data unit exchanged between entities at the same ISO layer.

Physical Layer (PHY): Layer 1 of the ISO/OSI reference model. The mechanism for transfer of symbols between HIPERLAN nodes.

Service Data Unit (SDU): Data unit exchanged between adjacent ISO layers.

time-bounded services: Time-bounded services denotes transfer services with low delay and low delay variance for use with voice and other real-time services.

[wireless] terminal adapter: The functional components of a network node that provide the communications services and the related control functions.

transceiver coverage area: The physical area serviced by a single transceiver.

uplink: The outgoing data direction from wireless terminal adapter perspective.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
AP	Access Point
ARQ	Automatic Retransmission reQuest
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
B-ISDN	Broadband Integrated Services Digital Network
BPN	Business Premises Network
CATV	Community Antenna TeleVision
CBR	Constant Bit Rate
CDV	Cell Delay Variation
CDVT	Cell Delay Variation Tolerance
CEPT	Conférence Européenne des administrations des Postes et des Télécommunications
CLR	Cell Lost Rate
CSMA	Carrier Sense Multiple Access
CTD	Cell Transfer Delay
DLC	Data Link Control
DPN	Domestic Premises Network
DSDU	DLC Service Data Unit
EY-NPMA	Elimination-Yield Non-pre-emptive Priority Multiple Access
FEC	Forward Error Correction
FPLMTS	Future Public Land Mobile Telecommunications System
HDTV	High Definition TeleVision
HIPERLAN	HIgh PErformance Radio Local Area Network
ISM	Industrial, Scientific and Medical
LAN	Local Area Network
LLC	Logical Link Control
LME	Layer Management Entity
MAC	Medium Access Control
MBS	Mobile Broadband Systems
MPDU	MAC Protocol Data Unit
MSDU	MAC Service Data Unit
N/A	Not Applicable
NTP	Network Termination Point
OSI	Open Systems Interconnection
PCMCIA	Personal Computer Memory Card Interface Association
PDA	Personal Digital Assistant
PDU	Protocol Data Unit
PHY	Physical Layer
PICS	Protocol Implementation Conformance Statement
P-NNI	Private Network-to-Network Interface
QoS	Quality of Service

RF	Radio Frequency
SDTV	Standard Definition TeleVision
SDU	Service Data Unit
UBR	Unspecified Bit Rate
UMTS	Universal Mobile Telecommunications System
UNI	User Network Interface
VBR-NRT	Non-Real-Time Variable Bit Rate
VBR-RT	Real-Time Variable Bit Rate
VCR	Video Cassette Recorder

4 Overview

The HIPERLAN family of standards addresses four types of HIPERLANs: HIPERLAN Type 1 (high speed wireless LANs), HIPERLAN Type 2 (short range wireless access to ATM networks), HIPERLAN Type 3 (remote wireless access to ATM networks) all operating in the 5 GHz band, and HIPERLAN Type 4 (wireless ATM interconnection) operating in the 17 GHz band. This is represented in the figure below together with the operating frequencies and indicative data transfer rates on the air interface.

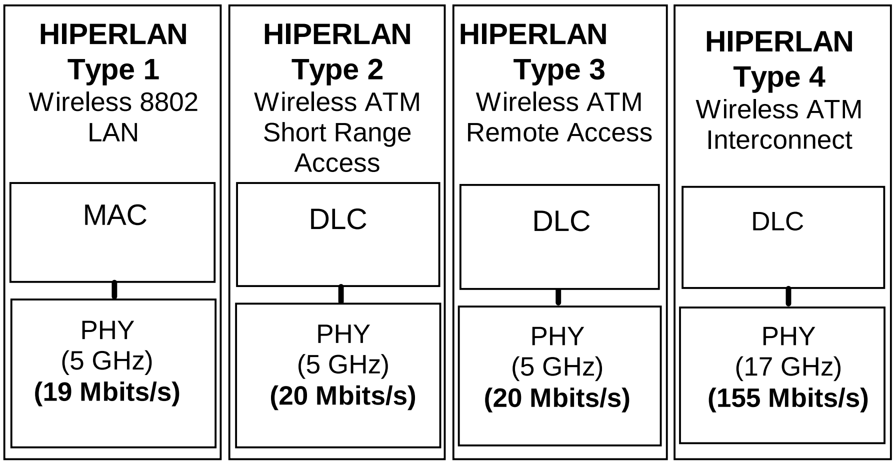

Figure 2: Overview of HIPERLAN Types

4.1 HIPERLAN Type 1, Wireless 8802 Local Area Networks

HIPERLAN Type 1 (HIPERLAN/1) is a wireless local area network that is ISO 8802 [5] compatible. It is intended to allow high performance wireless networks to be created, without existing wired infrastructure. Multiple HIPERLANs can co-exist in the same geographical area with equitable bandwidth sharing without co-ordination between them. In addition HIPERLAN Type 1 can be used as an extension of a wired local area network.

HIPERLAN/1 offers unconstrained connectivity based on directed one-to-one communications as well as one-to-many broadcasts. The channel provides both self configurability and flexibility of use thanks to a distributed channel access (EY-NPMA) and standardized forwarding feature.

The HIPERLAN/1 Functional Specification is given in ETS 300 652 [2].

4.2 HIPERLAN Type 2, short range wireless access to ATM networks

HIPERLAN Type 2 (HIPERLAN/2) is intended to provide local wireless access to ATM infrastructure networks by both moving and stationary terminals that interact with access points which, in turn, are connected to an ATM switch or multiplexer. A number of these access points will be required to service all but the smallest networks of this kind and therefore the wireless network as a whole shall support hand-overs of connections between access points. Further, such a wireless ATM access network shall be able to provide the Quality of Service (QoS), including required data transfer rates, that users expect from a wired ATM network.

4.3 HIPERLAN Type 3, remote wireless access to ATM networks

The increased penetration of ATM technology in transmission networks and the increased demand for high data rate interactive services make ATM based remote access systems an attractive option with a significant market segment. The data rate required is in the same range as for the local ATM access networks which can be shared by a number of users serviced by a single access point. As mobility support at high data rate is not needed, directional antennas can be used. This makes significant gains possible both range and re-use efficiency. HIPERLAN Types 2 and 3 can share many functions and therefore can share many implementation aspects.

4.4 HIPERLAN Type 4, wireless interconnect for ATM networks

Wireless ATM networks will also support infrastructure uses: the combination of low level switching and simple transmission units makes ATM the logical choice for both wired and wireless infrastructure networks, which require point-to-point connections. Interconnecting high data rate sources such as (access) networks requires high bitrates and large channel capacities. HIPERLAN Type 4 (HIPERLAN/4) provides point-to-point interconnection at very high data rates, e.g. up to 155 Mbit/s over distances up to 150 m.

4.5 A common wireless ATM architecture

HIPERLANs Type 2, 3 and 4 can be combined into a wireless architecture that meets the needs of a very large user population and that is flexible enough to last for the next ten years. This common wireless architecture provides three types of subnetworks (see figure 3) that interwork via standard ATM level functions and services.

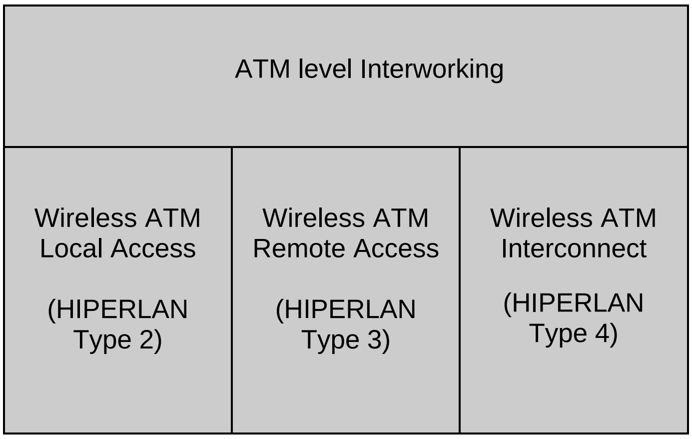

Figure 3: ATM level interworking between HIPERLAN Types 2, 3 and 4

5 Requirements

This clause deals with the general requirements that underlie the development of the HIPERLAN standards for wireless ATM access and interconnection.

5.1 Application environments

The following subclauses describe a number of application environments. The common denominator of these environments is that:

- they are used in a geographically limited area;
- they support multimedia services.

5.1.1 Types of HIPERLAN application environments

Domestic Premises Network (DPN) environment

The DPN environment covers the home and its immediate vicinity; it typically includes a localized radio extension to a broadband network. It is characterized by spot coverage areas, perhaps individual cells, one per home or building. Support for mobility beyond the coverage area is outside the scope of the present document.

Business Premises Network (BPN) environment

The BPN environment covers a privately owned network covering e.g. a company area, university or hospital campus, an industrial estate, etc. It may offer access, switching and management functions within an arbitrary large coverage area serviced by multi-cellular wireless communications facilities. Thus, functions like handover and paging may be necessary within this environment.

5.1.2 Types of networks

HIPERLANs may be used in a number of ways, for example:

Wireless Access to Public Network

HIPERLANs may be used to gain access to a public network, for example, to provide Telepoint services.

Wireless Access to Private Network

HIPERLANs may be used to gain access to a private network, for example, business premises or campus networks.

Wireless Infrastructure Network

HIPERLANs may be used to create both fixed, outdoor and portable in-door wireless infrastructure networks

Temporary Network

HIPERLANs may be used to create temporary networks, independent of an established wired local network. Such a network may be used semi-permanently, as an alternative for a wired network, and for ad-hoc purposes, for example for people to communicate and work on documents during a meeting.

5.1.3 Examples of HIPERLAN usage environments.

The table below shows various examples of HIPERLAN usage and applications in the networks types given above. A number of these application environments are analysed in the following subclauses.

Table 1: Examples of HIPERLAN usage environments

	Wireless Access to Public Networks	Wireless Private Networks (access- and infrastructure)	Temporary networks
DPN	- education - security, (sensors) - multimedia, e.g. radio CATV access point - mobile access to B-ISDN	- education security (surveillance and sensors) - domestic cordless multi-media distribution	- education - meetings - fairs - exhibition
BPN	- emergency networks telepoint - education - security, (sensors) - multimedia, e.g. radio CATV access point - mobile access to B-ISDN	- manufacturing - office automation - education - financial transactions - medical/hospital - security (surveillance and sensors) - broadcast studios - maintenance of large objects - stock control - aircraft gate link	- large meetings - offices - maintenance of large objects - industrial - emergency networks - exhibition

5.2 User scenarios

This subclause describes different scenarios in which HIPERLANs may be used.

- Infrastructure replacement scenario, i.e. when HIPERLANs could be used instead of cabling.
- Cordless access scenario, in which users need to use HIPERLANs in different locations at different times possibly maintaining connectivity while in transit.
- Wireless access to infrastructure scenario.
- Specialized portable applications scenario, i.e. user uses a PDA type device mainly for specialized applications, e.g. maintenance or surveillance.
- Domestic premises scenario, i.e. HIPERLANs are used in the home environment.
- Wireless manufacturing automation scenario, i.e. HIPERLANs are used in a factory or a large assembly / building facility.
- Inter network communication scenario.

5.2.1 Infrastructure replacement scenario

HIPERLANs can be used for wired infrastructure replacement in a number of scenarios including the replacement of a wired premises networks. Typical cases could be temporary office installations or installations into spaces where building characteristics or protection prohibit the extensive use of a cabling.

The infrastructure to be replaced includes stationary backbone networks operating at high speeds as well as wireless network terminations.

Terminals typically connected to infrastructure networks typically are designed for fixed use. Such a terminal could, for example, be a workstation, a PC or any other purpose specific terminal. The applications are typically broadband applications. In this scenario the user device is mostly stationary and the main benefit derived from HIPERLANs is the wireless dimension. Thus, HIPERLANs shall provide or approximate fixed network QoS to a stationary user. The user should not be able to notice the difference between using the wireless system and a wired system.

Table 2: An example of a wired infrastructure replacement scenario

Attribute	
End-user equipment	PC or work station
Usage environment	Offices etc.
Range	Up to 50 meters for indoor systems; Up to 5 km for outdoor systems.
QoS expectation	Same as desktop
Applications	Same as desktop
Mobility	Limited
Coverage	Continuous
User Density	High

5.2.2 Cordless access scenario

In this scenario, the HIPERLAN user needs to perform his or her work at different locations at different times. The main end-user equipment would be a portable computer. Typically such a user would carry a portable computer to various places within the office and then use the computer while stationary. Typical places for using the HIPERLAN system outside a office room would be meeting rooms, dining facilities, patient wards, class rooms and auditoria as well as waiting rooms/halls. A cordless user will also access the public network, through basestations installed in locations such as railway stations, airports and shopping centres. In some cases, connectivity has to be maintained while the user is in transit from one location to another.

The terminals in this scenario are movable. A typical terminal could be built around a laptop computer and a HIPERLAN card. The mobile node will in many cases be a battery driven device so that an economic consumption of power is required.

Table 3: An example of a cordless access scenario

Attribute	
End-user equipment	Portable computer, e.g. Notebook or Palmtop.
Usage environment	Offices, schools, hospitals, airports, railway stations, shopping centres, etc.
Range	Up to 50 meters for indoor systems; Up to 150 meters for outdoor systems.
QoS expectation	Similar to desktop
Applications	Similar to desktop
Mobility	none during use
Coverage	Continuous
User Density	High (e.g. in a meeting room)
Power consumption	Low

5.2.3 Specialized portable applications scenario

In the third scenario a user has a small (possibly dedicated) system like a PDA to access services. The applications are typical broadband applications which shall be supported for mobile users with an acceptable QoS by the mobility functions in the network, e.g. handover. The QoS expected from the HIPERLAN system in this scenario could however be somewhat lower than the QoS of a fixed system. The user can be assumed to realize that a small loss in QoS is the price paid for the mobility gained. For example, the connection might tolerate a short interruption because of a handover (resulting in momentary disturbance in the video picture) etc.

The terminal in this scenario is a mobile handheld terminal e.g. a PDA with a wireless network card or a dedicated mobile node. The applications are mostly dedicated mobile applications that are capable of operating at a lower QoS, as they would use mobile specific features to compensate for some mobile related problems.

The mobile node will in many cases be a battery driven device so that an economic consumption of power is required.

Table 4: An example of a specialized portable scenario

Attribute	
End-user equipment	Hand portable unit, PDA
Usage environment	Anywhere within or near private premises
Range	Up to 50 meters for indoor systems; Up to 150 meters for outdoor systems.
QoS expectation	Modest, but maintained during movement
Applications	Dedicated, could be mobile specific
Mobility	Walking speed or slow vehicle (e.g. forklift)
Coverage	Continuous
User Density	Low
Power consumption	Very low

5.2.4 Domestic premises scenario

In the domestic network scenario, many appliances, e.g. PC laptop, printer/fax machines, security systems, home appliances, digital HDTV/SDTV sets, digital Video Cassette Recorder (VCR), speakers and more could be linked in various ways. A typical scenario would be:

1) An entertainment cluster (video and sound) located in the living room transmitting to television sets located in the living room, kitchen and bedroom.

2) A music system in the living room transmitting to speakers located in the living room, bedroom or dining room.

3) Security features outside the home such as wireless security camera or remote sensors. These could either be located on the external walls of the property or at the boundary wall or a remote building such as a garage or recreation facility.

4) Outdoor speakers for barbecue/party. Assuming that the music system is located in the entertainment cluster in the living room, the transmission path and length may extend into the garden.

From the above, it is obvious that the domestic network shall allow access to external networks e.g. digital television or be capable of working with no external links e.g. a music system with remote speakers. This system should be easily installable by non-technical people.

A domestic network generally covers a much smaller area than either factory or office environments. The rooms in a domestic premises tend to be smaller when compared to work environments and have more compartmentalized structure (storage spaces and en-suites).

Table 5: An example of a domestic premises scenario

Attribute	
End-user equipment	Computer, television, entertainment cluster, security systems, etc.
Usage environment	Domestic premises, i.e. small rooms with high attenuation
Range	Up to 15 meters
QoS expectation	Consistent with real-time multi-media services
Applications	Real-time multi-media
Mobility	Walking speed
Coverage	Continuous
User Density	Low

5.2.5 Industrial and transportation scenario

In manufacturing scenarios such as process automation, commissioning systems, baggage transfer, distribution systems, warehouse storage and retrieval services we have a large number of intelligent transportation elements which may move autonomously and automatically in a factory hall, a storage building, or in an airport. Such a system should cover approximately an area of 250 m × 250 m. Delay values and data losses are critical. The ability to support highly reliable real-time control and alarm data as well as other time bounded services is mandatory. Power consumption and the physical size of the communication device are not as critical as in other scenarios.

Table 6: An example of a manufacturing scenario.

Attribute	
End-user equipment	Intelligent transportation elements, autonomous, automatic vehicles, surveillance systems, monitors
Usage environment	Factory halls, airports, storehouses, industrial environments
Range	Up to 50 meters. Shadowing, highly variable radio channels
QoS expectation	Low delay, high error sensitivity, time bounded, real-time, short packets
Applications	Mobile, file transfer, control, alarms, surveillance, monitoring
Mobility	< 10 m/s
Coverage	Continuous
User Density	High (variable)
Power consumption	Not critical

5.2.6 Network interconnection scenario

In this scenario, HIPERLANs may be used to interconnect remote networks, via a high data rate wireless ATM link. A typical application is LAN interconnection between buildings within a university or hospital campus. Here HIPERLAN would serve as a fixed link over distances of up to 5 km (using directional antennas).

Table 7: An example of a network interconnection scenario.

Attribute	
End-user equipment	Fixed communication equipment
Usage environment	Private, intra- and inter campus
Range	Up to 5 km
QoS expectation	High
Applications	N/A
Mobility	None
Coverage	Point-to-point
User Density	N/A
Power consumption	Not critical

5.2.7 Wireless access to fixed networks scenario

In this scenario, the HIPERLAN system provides a licence-exempt wireless access to fixed network, normally from the local exchange to a Network Termination Point (NTP) serving e.g. business premises, a campus or a family home. Another example would be a "set top box", to which user devices round the home would be connected, providing services such as video-on-demand, computing, Internet access and network games.

Table 8: An example of a wireless access scenario.

Attribute	
End-user equipment	Various, connected to some NTP
Usage environment	Access to Fixed Networks
Range	Up to 5 km
QoS expectation	High
Applications	N/A
Mobility	None
Coverage	Directional
User Density	Low
Power consumption	Not critical

5.3 Application requirements

There are many applications that together form the requirements for wired as well as wireless systems. Many of these will be covered in later clauses, but a general application type, the multimedia application deserves special attention. Multimedia applications are becoming popular and are already beginning to demand wireless transport with a high quality of service. Multimedia applications shall be taken into account when defining the HIPERLAN family.

Multimedia covers anything from basic messaging through to audio, video or any combination thereof. At the transport layer multimedia consists of two types of information flow; firstly the delivery of fixed packages of information and secondly the delivery of a stream of information which can be described by a certain data rate and delay tolerance.

ATM is a transport mechanism which has been designed to cater specifically for multimedia by being able to support very different kinds of connections with different QoS parameters. The progress towards ATM transport in fixed networks has already started and the market push is strong and growing. Therefore it can be expected that new applications will be developed which fully exploit the capabilities of the ATM transport technology, especially the availability of high bandwidth. As users get accustomed to this level of service they are going to demand the same QoS on wireless systems. HIPERLANs shall specifically support ATM applications and QoS.

The following subclauses describe a number of scenarios for HIPERLAN deployment. Two main scenarios are described, corresponding to an office and an industrial application. Each scenario is broken down further into typical activities and shows estimated data rate requirements for each activity. The purpose of this analysis is to provide a thorough basis for an estimate of HIPERLAN spectral requirements.

5.3.1 Office HIPERLAN deployment scenario

The following activities are expected in an office deployment scenario for HIPERLAN over the next two or three years. The required data rates for each activity are given in a spreadsheet (table 9). Table 9 also shows the calculation of an average data rate required to support the listed activities for each person in the office. These figures will be used shortly to compute estimates of the spectrum required to support typical office use of HIPERLANs. A list and brief description of office related activities that could be supported by HIPERLANs follows:

Multimedia conference (large video displays)

High quality video/audio channels with multiparty data links for the transmission of still images or other types of computer data.

General video conferencing

Symmetric, High quality, multiparty video conferencing.

Asymmetric video

Asymmetric due to poor resolution of mobile terminal video display.

Telephone

From toll quality telephone service to higher quality audio.

General networked computing applications

Examples of applications are: Client-server, Processing, Printing, E-mail, Messaging, Fax, Groupware, Games and Simulations, Network file systems, etc. The transfers are generally asymmetric and highly bursty. The data rate requirements are quite dependent on the level of mobility, i.e. the quality should be very similar to that one offered by a fixed LAN on a static mobile node, and temporarily degraded while on the move. Moreover, the bit rate should correspond to the processing speed of the terminal i.e. PDA, portable computer or workstation.

The requirements for a wired-LAN QoS are upper bounds and may be considered as a basis for a wireless LAN:

Multimedia database

Encyclopaedia, diagnosis, electronic newspaper, bulletin board, World Wide Web, manuals, etc. Asymmetric, resource demanding application, bursty non-real-time data.

Security and monitoring

Surveillance video/audio, Industrial or office security service, Alarms, etc.

Internet and Intranet Browsing

The Internet has gained prominence far beyond the expectations expressed by experts only a few years ago. Today businesses of all kinds make extensive use of Internet and Intranet as a means to disseminate information about their products and services. Similarly, government institutions are getting ready to put their information on the Net. With the emergence of electronic payment the Net will become a commercial environment as well. For many international organizations, including ERO and ETSI, the Net has become an indispensable tool. As a consequence users spend hours a day "surfing" the Net to find and exchange information. This information is typically not just text form but includes extensive graphics as well as, in some cases, video and audio sequences.

Teleworking

Less prominent but gaining ground is the notion of teleworking. Teleworking may mean working at home but being in contact with colleagues at work and with customers through video/voice/data sessions. It also means collaboration between geographically separated persons, possibly a group of them. Here too, the ability of telecommunications to deliver high quality video and sound as well as real time data allows users to avoid costly and time consuming travel. Application developers have caught on to this opportunity. A variety of "screen sharing" tools is being developed that provide users with the means to work together in real time on the same electronic documents while being in eye and ear contact. Much like the Net browsers opened up the demand for Internet services so these sharing tools will create a large demand for teleworking services.

Table 9: Predicted average data rate per HIPERLAN, office deployment

Office application	Link direction	Average data rate	Typical peak/average ratio	Peak data rate	Office application usage	Weighted average data rate	
		bits/s		bits/s	%	bits/s/HIPERLAN	
1. Video applications							
1.1 Multimedia conference, (large displays)							
	Uplink	1,50E+06	2,00	3,00E+06	1,00%	1,50E+04	
	Downlink	7,50E+06	1,50	1,13E+07	1,00%	7,50E+04	
1.2 General video conferencing							
	Uplink	7,50E+05	2,00	1,50E+06	3,00%	2,25E+04	
	Downlink	2,25E+06	1,50	3,38E+06	3,00%	6,75E+04	
1.3 Asymetric video							
	Uplink	7,50E+05	2,00	1,50E+06	1,00%	7,50E+03	
	Downlink	1,28E+05	1,00	1,28E+05	1,00%	1,28E+03	
2. Telephone	Uplink & downlink	3,40E+04	1,00	3,40E+04	6,00%	2,04E+03	
3. General networked computing applications							
3.1 Data transmission							
	Uplink & downlink	2,50E+07	5,00	n/a	3,00%	7,50E+05	
3.2 Document retrieval							
	Uplink & downlink	2,00E+06	20,00	n/a	5,00%	1,00E+05	
3.3 E-mail							
	Uplink & downlink	5,00E+04	3,00	n/a	10,00%	5,00E+03	
3.4 Processing (Host 0.5 MIPS)							
	Uplink & downlink	5,00E+04	5,00	n/a	15,00%	7,50E+03	
3.5 Processing (Host 5.0 MIPS)							
	Uplink & downlink	3,00E+05	5,00	n/a	15,00%	4,50E+04	
3.6 Monochrome laser printing							
	Uplink & downlink	1,28E+05	5,00	n/a	5,00%	6,40E+03	
4. Multimedia database							
	Uplink	1,00E+04	10,00	1,00E+05	8,00%	8,00E+02	
	Downlink	1,00E+05	10,00	1,00E+06	2,00%	2,00E+03	
5. Security and monitoring							
	Uplink	7,50E+05	2,00	1,50E+06	0,50%	3,75E+03	
	Downlink	6,40E+04	1,20	7,68E+04	0,50%	3,20E+02	
6. Internet and intranet browsing							
	Uplink	2,40E+03	10,00	2,40E+04	8,00%	1,92E+02	
	Downlink	1,00E+05	10,00	1,00E+06	2,00%	2,00E+03	
7. Teleworking							
	Uplink	1,00E+05	15,00	1,50E+06	5,00%	5,00E+03	
	Downlink	5,00E+05	5,00	2,50E+06	5,00%	2,50E+04	
				TOTALS:	**100,00%**	**1,14E+06**	**bits/s/HIPERLAN**
Note: Peak data rates are not applicable where applications are insensitive to the data transfer delay.							

5.3.2 Industrial HIPERLAN deployment scenarios

Table 10 provides a breakdown of the data rate capacity required to support a typical industrial deployment of a HIPERLAN network on a piece of industrial plant or machinery assumed to contain 50 separate HIPERLAN equipments operating in a single radio locale defined by the operating radio range. A more general list of industrial activities that can be supported by HIPERLAN follows:

Gatelink

Gatelink is a typical example of multimedia networking in an industrial environment. The applications are in aircraft maintenance support, software loading of airborne systems, passenger service and entertainment, pilot briefing and backup of aircraft maintenance systems. The data rate requirements of Gatelink are not analysed further in the present document.

Manufacturing Applications

In process automation, commissioning systems, baggage transfer and distribution systems we will find a mixture of services. Services will include non-real-time data for file transfer, software and configuration data download, as well as very time critical (real time) data transfer for control and alarm data. Also a mixture of conversational multimedia services for surveillance and monitoring purposes is needed.

Industrial Remote control

Remote control of some device. High quality asymmetric video/audio (MPEG-1 or MPEG-2, possibly multichannel and/or stereo picture) , control information and computer data.

Industrial monitoring

Industrial monitoring is a specific application in industrial environments. The applications are for instance monitoring of oil pipelines or monitoring of production processes and resources like tanks in chemistry plants. Data is typically generated by a sensor, is very small as well as specific and has very stringent delay bound and variance. Normally the bandwidth needs are low. However, in certain circumstances (for instances fire or explosions) a very bursty and strongly correlated traffic can be generated by hundreds (thousands) of sensors which has to be handled by the network according to the QoS requirements.

Table 10: Predicted average data rates per HIPERLAN for an industrial deployment

Industrial application	**Link direction**	**Average data rate**	**Typical peak/average ratio**	**Peak data rate**	**Industrial application usage**	**Weighted average data rate**	
		bits/s		bits/s	%	bits/s/plant	
1. File transfer							
	Uplink & downlink	2,00E+06	5,00	1,00E+07	2,00%	4,00E+04	
2. Software transfer							
	Uplink & downlink	4,00E+05	2,00	8,00E+05	1,00%	4,00E+03	
3. Configuration data							
	Uplink & downlink	6,00E+05	20,00	1,20E+07	1,00%	6,00E+03	
4. Control data							
	Uplink	2,10E+07	2,00	4,20E+07	25,00%	5,25E+06	
	Downlink	2,10E+07	2,00	4,20E+07	25,00%	5,25E+06	
5. Alarms							
	Uplink & downlink	2,00E+04	20,00	4,00E+05	1,00%	2,00E+02	
6. Surveillance							
	Uplink & downlink	1,40E+07	2,00	2,80E+07	3,00%	4,20E+05	
7. Monitoring							
	Uplink & downlink	5,00E+05	1,00	5,00E+05	20,00%	1,00E+05	
8. Video multipoint monitoring							
	Uplink	7,50E+05	2,00	1,50E+06	10,00%	7,50E+04	
	Downlink	2,25E+06	1,50	3,38E+06	10,00%	2,25E+05	
9. High bandwidth video multipoint monitoring							
	Uplink	1,50E+06	2,00	3,00E+06	1,00%	1,50E+04	
	Downlink	7,50E+06	1,50	1,13E+07	1,00%	7,50E+04	
		TOTALS:			**100,00%**	**1,15E+07**	**bits/s/plant**
		Assuming there are 50 HIPERLANs per plant:				**2,29E+05**	**bits/s/HIPERLAN**

5.3.3 Other HIPERLAN deployment scenarios

HIPERLAN can support many other activities and deployment scenarios other than those listed above. A number of the more prominent examples of alternative HIPERLAN deployments are described below and a TV, radio or recording studio deployment containing about 60 separate HIPERLAN equipments is analysed further in table 11:

- Audio distribution.
- High quality audio.
- High quality Audio distribution.
- High quality e.g. delivery of audio or wireless equipment for programme production (possible multiparty).
- Database services.

Inventory of available goods, On-floor customer services in shops, Menu of the company cafeteria, Telephone and contact information directory, etc. This deployment scenario is identified, but not analysed further in the present document.

Table 11: Predicted average data rates for broadcast or recording studio HIPERLAN deployments

TV, radio or recording studio HIPERLAN application	Link direction	Average data rate	Typical peak/average ratio	Peak data rate	Studio application usage	Weighted average data rate	
		bits/s		bits/s	%	bits/s/deployment	
1. Audio distribution, 8 channels							
	Uplink & downlink	3,07E+06	1,00	3,07E+06	10,00 %	3,07E+05	
2. High quality audio uplink, 1 stereo channel							
	Uplink	3,84E+05	1,00	3,84E+05	10,00 %	3,84E+04	
3. Telephone headsets, 10 lines							
	Uplink & downlink	6,40E+05	1,00	6,40E+05	10,00 %	6,40E+04	
4. Radio microphones, 30 off							
	Downlink	1,15E+07	1,00	1,15E+07	30,00 %	3,46E+06	
5. High quality video distribution, 8 channels							
	Downlink	1,20E+07	1,00	1,20E+07	30,00 %	3,60E+06	
6. High quality video uplink, 1 channel							
	Uplink	1,50E+06	1,00	1,50E+06	10,00 %	1,50E+05	
				TOTALS:	**100,00 %**	**7,62E+06**	**bits/s/deployment**
		Assuming there are 60 HIPERLANs per deployment:				**1,27E+05**	**bits/s/HIPERLAN**

5.4 Summary of data rate requirements for HIPERLAN deployments

A summary of the data rate requirements based on the example deployments listed above and analysed in tables 9,10 and 11, is given in table 12. The table includes some reasonable assumptions for the numbers of HIPERLAN terminals that would exist in each deployment and shows how the total data rate is calculated in each case. The table also includes factors for the efficiency of the network protocol (e.g TCP/IP) and for the protocol efficiency of the air interface which takes into account the signalling traffic generated by the operation of the HIPERLAN MAC protocol which reduces the available channel capacity.

Table 12: Summary of data rate requirements for HIPERLAN deployments

Deployment example:	**Average data rate required per HIPERLAN**	**Number of HIPERLANs per deployment**	**Network access duty cycle**	**Useful data rate required per deployment**	**Network protocol overhead**	**HIPERLAN protocol efficiency**	**Total data rate required per deployment**
	bits/s/HIPERLAN		%	bits/s/deployment	%	%	bits/s/deployment
	D_u	N_h	A_u	$D_u*N_h*A_u$	P_a	P_e	$D_u*N_h*A_u /(P_a*P_e)$
Office	1.1438E+06	1200	10%	1.3725E+08	65%	50%	4.2232E+08
Industrial	2.2920E+05	250	100%	5.7301E+07	65%	50%	1.8909E+08
Studio	1.2693E+05	60	100%	7.6156E+06	65%	50%	2.5131E+07

5.5 Spectrum requirements

5.5.1 Wireless access networks

The spectrum requirements presented below are based on the required useful data rates analysed above for a large office area with access to a wired network scenario and certain assumptions about spectrum re-use factor and the spectral efficiency of the modulations that can be used. The following spectral requirements should be treated as typical values to guide decisions about present and future spectrum designations.

Total area covered: 24 000 m^2, (approx 160 metres × 160 metres).

Number of users: 1 200 (at 20 square metres per user).

Total data rate required: 412 Mbit/s/deployment (see table 12).

Modulation efficiency: 1 bit/s/Hz.

Access point bandwidth: 25 MHz (governed by peak data rates needed for multimedia conferencing, as shown in table 9).

Minimum number of access points = 412 / 25 = 17.

Access point spacing = SQRT(24 000 / 17) = approx. 40 metres at most.

Frequency re-use factor: 1/10 (see note).

Therefore 10 × 25 = 250 MHz of spectrum is required to support this scenario.

NOTE: Experience from cellular radio shows that a frequency reuse factor of 1/7 is possible, but only where systems are carefully frequency planned. Since HIPERLANs operate in unlicenced and uncoordinated spectrum a lower figure is inevitable. A factor of 1/10 is an ambitious goal, assumed to be realizable where access points are spaced at 40 metres.

The modulation efficiency is assumed to be 1 b/s/Hz. This spectral efficiency is considered achievable for a number of different modulation and channel coding schemes that might be specified for HIPERLANs.

The above figures show initial HIPERLAN spectrum requirements of 250 MHz. User traffic densities will increase in the future and will not be supportable with a spectrum re-use factor of 10. Higher traffic densities will require higher spectral re-use factors which will increase the spectrum required well above 250 MHz.

5.5.2 Wireless infrastructure networks

A wireless infrastructure, e.g using HIPERLAN Type 4, that connects wireless access networks to each other and to one or more wired networks should be able to support a large corporation, a university or industrial estate. The following assumes 1 200 users to be active at such a site. Assuming an average user requirement to be the same as given table 12 for the office environment, this requires an aggregate capacity over all point-to-point links in excess of 412 Mbits/s.

Since the type of connection is basically a static point-to-point connection, directional antennas could be used to advantage in order to achieve both higher bitrates and to improve spectrum re-use dramatically.

Using narrow antenna beams, multipath effects are largely eliminated and the bit rate of the infrastructure links can be much higher than "omni-directional" links. It seems safe to assume that 155 Mbits/s is economically achievable with 200 MHz. This rate matches a basic ATM transmission rate. However at longer distances, this high rate may not be achievable.

Assuming that antenna selectivity allows a spectrum re-use factor 15 (e.g. 15 directional links can share the same physical area, gives a raw capacity of 15 × 155 Mbits/s or 2 325 Mbits/s. Even allowing for a significantly lower re-use factor, this figure is sufficient to cover the projected requirements for the foreseable future.

6 General considerations

6.1 Regulatory constraints

Spectrum has been designated by the CEPT for the licence exempt use of HIPERLAN systems. At the time of writing the present document, 100 MHz of spectrum has been designated in the 5 GHz band for HIPERLAN, with a further 50 MHz available at the discretion of National Administrations (see CEPT Recommendation T/R 22-06 [1]). Also, 200 MHz is available in the 17 GHz band. HIPERLAN systems shall operate on a non-interference, non-protected basis. Licence exempt use implies the HIPERLAN systems should be able to co-exist with each other and with other radio services in the band and not cause undue interference. This will have implications for the design and specification of medium access methods and for type approval regimes for HIPERLAN equipment. Where different HIPERLAN types are required to share the same frequency band, equitable spectrum sharing rules are required as part of the type approval regime.

6.2 Radio technology constraints

Technically, the lower frequencies are better suited for the mobile components because antenna efficiency is sufficient to allow the use of omni-directional antennas at the permitted RF power level of 1 Watt peak eirp (see CEPT Recommendation T/R 22-06 [1]). With extensive signal processing, it is possible to achieve a range of 20 to 50 meters indoors at 5 GHz, depending on the environment. Outdoors at 5 GHz the range may be greater.

In the 17 GHz band assigned to HIPERLANs, only 100 mW RF power is allowed (see CEPT Recommendation T/R 22-06 [1]). With omni-directional antennas, range would be limited to a few meters. This makes its use for portable applications costly and inefficient. However, at these frequencies, the use of directional antennas is very effective and less cumbersome physically than at 5 GHz or lower frequencies. Therefore the 17 GHz band is best suited for infrastructure type networks.

Other considerations that govern the choice of frequency for mobile or stationary applications are:

1) RF component efficiency: the higher the operating frequency, the lower the efficiency of the RF power stage and other components. Stationary applications can bear this inefficiency much easier than mobile applications where (battery) power is a major factor.

2) RF component cost: the cost goes up with frequency. Here too it is the stationary applications that bear these higher costs more easily.

3) Wall attenuation: this too goes up with frequency, making continuous coverage diffucult to achieve for systems supporting mobility. Point-to-point links, on the other hand, can be engineered to avoid this problem.

6.3 User data security and privacy requirements

Users of HIPERLAN devices require protection of their transmissions from being listened to by other users operating possibly co-located HIPERLANs. In addition they may require protection against misuse of their wireless networks by third parties.

The protection from disclosure requires the implementation of a data confidentiality service. The level of protection provided shall be consistent with the protection provided by wired systems that do not implement a data confidentiality service. Further, the cryptographic algorithm shall not be subject to export controls and therefore allow world-wide use.

NOTE: Confidentiality services may be available within the host systems that make use of HIPERLAN subsystems. Therefore, a confidentiality service within the HIPERLAN subsystem should be an optional feature that users can activate as required.

The protection from misuse by third parties is a systems concern that is common to all communications systems. This cannot be completely addressed within the scope of the HIPERLAN standards since these cover only the lower layers of the communications architecture.

6.4 Human safety

HIPERLAN standards shall reference and comply with any appropriate human safety standards. It should be noted that HIPERLAN systems may not be suitable for use in safety critical applications.

7 HIPERLAN Type 2

HIPERLAN Type 2 (HIPERLAN/2) systems provide short range, wireless access to multi-media services over ATM. The scope of HIPERLAN/2 is limited to the air interface, the service interfaces of the wireless subsystem and supporting capabilities required to realize these services.

Interfaces between the signalling functions in ATM terminal devices and in the ATM switch are outside the scope of HIPERLAN/2.

The following text outlines requirements, to be used as basis for the development of a functional standard.

Currently available standards for ATM systems include: the ATM Physical Media layer (the bit transport), the ATM layer itself (cell processing and switching) and signalling protocols to support the connection set-up and release procedures (Signalling AAL), and a number of ATM Adaptation Layers (AALs) that enhance the basic ATM service to a level required by specific ATM service classes. See annex A for further details.

7.1 Reference model

7.1.1 Services and capabilities

7.1.1.1 Services

HIPERLAN/2 shall provide the following services:

1) Connection set-up with parameter negotiation for QoS consistent with ATM service CBR, VBR-RT, VBR-NRT, ABR, UBR. Outgoing and incoming connections shall be supported. Device addressing shall be consistent with world-wide roaming.

2) Releasing incoming connections and outgoing connections.

3) Unit data transfer [= ATM cells with Loss Priority Indication].

NOTE: Unit Data transfer comprises both Request (= transmit) and Indication (= receive) primitives.

HIPERLAN/2 shall implement traffic management within each access subnetwork to maximize adherence to QoS parameters established at connection set-up.

7.1.1.2 Supporting capabilities

HIPERLAN/2 shall provide the following capabilities in support of the above services:

1) Association of wireless terminalss in a logically distinct access subnetwork.

2) Informing the ATM switch that hosts an access subnetwork of the changes in the population of associated wireless terminals.

3) Monitoring of radio conditions as basis for handover between access sub-networks and for informing user and hosting ATM switch of the prevailing radio/traffic conditions.

NOTE 1: This capability is required to support Terminal initiated handover between access sub-networks without loss of connection and with limited loss of Quality of Service.

4) Support for Power Conservation.

5) Dynamic allocation of radio link capacity.

NOTE 2: The provision of peer-to-peer and ad-hoc capabilities is for further study.

7.1.2 Layer architecture

The following figure gives a possible Mobility enhanced ATM switch /Access point/Wireless terminal configuration.

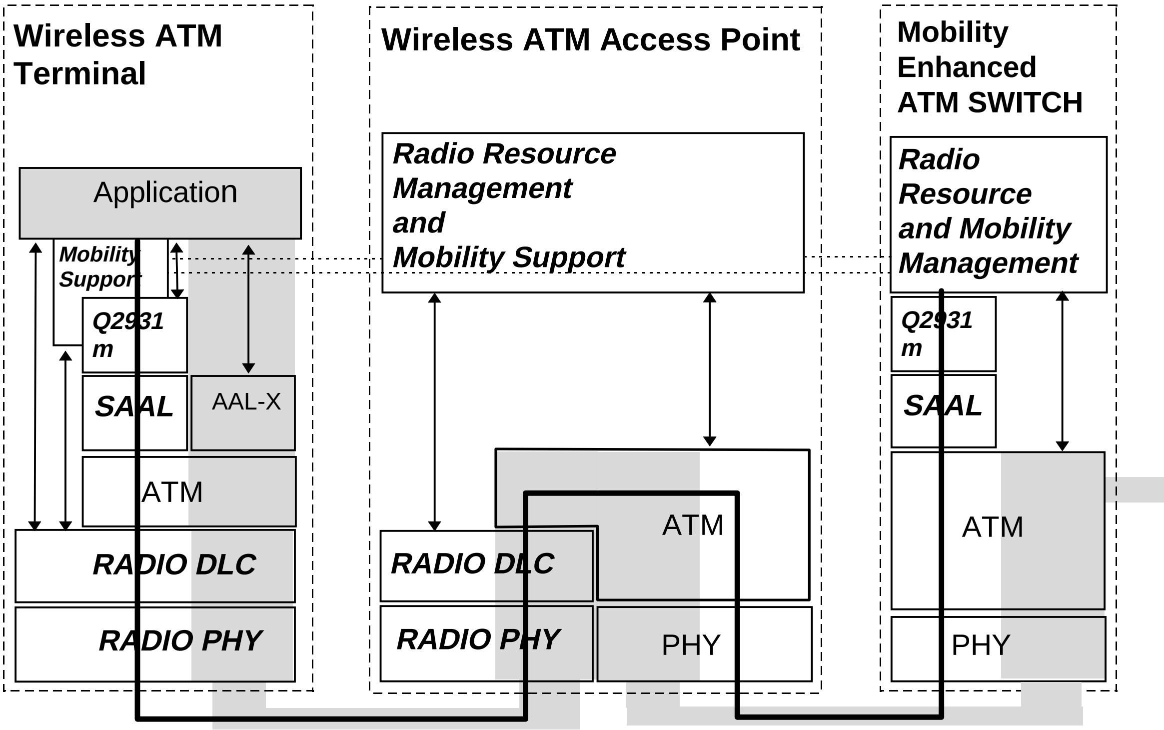

Figure 4: HIPERLAN/2 layer architecture

The thick dark line indicate call control flows, the dashed lines special protocols between the three system elements, the grey band indicates user data flow. The thin black lines show the "off stack" control interfaces that allow user provided functions to control Radio DLC functions like (DLC) connection set-up and releasing.

Q.2931 m is an extension to ITU-T Recommendation Q.2931 [4] which is described in subclause 7.1.3.

This architecture supports the transparent transfer of ATM cells and hence it allows the use of all existing and new types of ATM adaptation layers (AAL-X in figure 4) to the extent that these maintain compatibility with the existing ATM service definitions and protocol specifications.

The access point acts as a multiplexer that supports mobility of wireless terminals within the access subnetwork serviced by the access point. It also provides information to the Mobility Enhanced switch that is needed to support wireless terminal mobility with the access network.

NOTE 1: The functions needed to support roaming between different sites/switches is outside the scope of the present document.

The Radio DLC layer contains two sublayers: a Medium Access Control sublayer (MAC) and a Logical Link Control sublayer (LLC).

The MAC sublayer implements a service policy that takes into account such factors as Qulaity of Service per user connection, channel quality, number of terminal devices and medium sharing with other access sub-networks.

The LLC sublayer maintains the quality of service on a virtual circuit basis. Depending on the type of service provided and channel quality, capacity and utilization, the LLC layer will implement a variety of means including FEC, ARQ and flow pacing to optimize the service provided to the (DLC) user.

NOTE 2: Within the ATM community, Generic Flow Control is being discussed - this may impact the functionality of the DLC layer and its service definition.

NOTE 3: Usage Parameter Control is an optional capability of ATM systems that may have impact on the specification of the Radio DLC layer and on the access point behaviour.

7.1.3 Interworking

HIPERLAN/2 Interworking requirements include:

1) Interworking at the ATM layer so as to provide a transparent service to the ATM service users; this includes extension of ITU-T Recommendation Q.2931 [4] for signalling and connection set-up and releasing functions. The extensions to ITU-T Recommendation Q.2931 [4] are outside the scope of HIPERLAN/2; these specifications are expected to be developed by the ATM Forum.

2) Interworking between the access point and the ATM switch Resource management functions in support of mobile (as opposed to stationary) terminals.

7.1.4 Addressing

HIPERLAN/2 wireless terminals shall be addressable by their global address (so as to support world-wide and nomadic use).

Internally, an access subnetwork may use abbreviated addressing of some kind in order to reduce protocol overhead.

7.1.5 Reference model

The HIPERLAN/2 reference model identifies the following reference points:

Reference point H2.0: the interface between the HIPERLAN/2 user and the wireless terminal adapter. It is defined in terms of abstract services and parameters for the user, control and management planes.

Reference point H2.1: defines the interface between the fixed network and the wireless ATM terminal. It is an interoperability interface that includes the following protocol definitions:

- The air interface protocol between the wireless terminal adapter and the access point. It includes the DLC protocol that supports transparent ATM transport (User, Control and Management plane traffic) as well as mobility support functions such as access point acquisition and association or system functions such as channel occupancy signalling.
- The control plane signalling protocol between the mobility enhanced ATM switch and the mobile terminal. It includes the protocol for user registration and connection set-up and -releasing as well as protocol elements for mobility support including handover. This protocol is carried over the air interface protocol.
- The standard ATM user plane protocol.

Reference point H2.2: the interface between the access point and the ATM Switch and its management and control functions. It is an interoperability interface that includes the following specifications:

- The protocol that describes the interactions between the access point and the ATM Switch for the establishment and releasing of connections, for connection handover between access points and for capacity management purposes.
- The standard ATM PHY user plane protocol.

NOTE: The access point may be considered to consist of one or more access point transceivers connected to a single access point controller. The interface between these two elements would not be visible. The use of multiple transceivers has implications for the handover procedures.

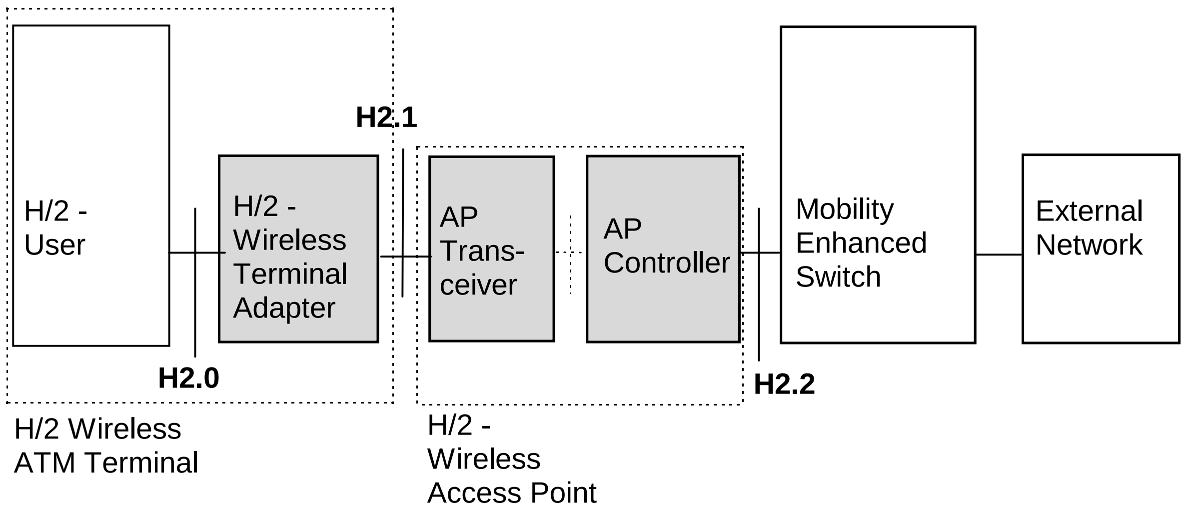

Figure 5: HIPERLAN/2 reference model

The HIPERLAN/2 standard shall describe the mechanisms of the Service Interface at the H2.0 reference point and the Air Interface Protocol at the H2.1 reference point. Specifications of other interfaces and functions are outside the scope of the HIPERLAN standards. In this case, the ATM Forum is the expected source of the other specifications.

7.2 Mobility support

HIPERLAN/2 shall support:

1) Roaming between access networks (with connection release and (re) set-up).

2) Continuous service while in motion within the contiguous area covered by the access network connected to a given switch.

The rate of movement to be supported is:

1) m/s linear

2) deg/sec rotation

7.3 Requirements imposed on radio sub-system

7.3.1 Radio range

HIPERLAN/2 shall provide a range of 50 m in a typical indoor environment and up to 200 m in a typical outdoor environment.

7.3.2 Data rate

HIPERLAN/2 shall provide a data rate at the air interface capable of supporting at least 30 K ATM cells/sec/terminal in a typical indoor environment.

In other conditions the minimum rate may be lower; this is for further study.

7.3.3 Capacity

The capacity in terms of bits/s/hect of a HIPERLAN/2 network is limited by the number of RF channels available and the loading of these channels by HIPERLAN/2 networks operating in radio range of each other.

Further, the actual capacity of a HIPERLAN/2 system depends on the protocol overhead, on the ratio between protocol overhead and traffic payload size and on the effective channel isolation.

7.3.4 QoS, user data rate, transfer latency and transfer delay variance

When operating in an environment that does not vary, HIPERLAN/2 systems shall be able to maintain the data rate and QoS values of connections established at connection set up. For the applicable QoS parameters, (see ITU-T Recommendation I.356 [9] and equivalent ATM Forum documents).The following values are provided as guidelines for the Cell Transfer Delay and Cell Delay Variance:

1) Cell Transfer Delay: < 5 msec.

2) Cell Delay Variance: < 1 msec.

These figures may not be realizable under all conditions and for all service categories.

1) They are based on the following: since cell transfer delay and cell delay variance accumulate along a communications path, these values are reasonable target values that allow additional delay in other network components.

2) The cell transfer delay of 5 msec allows a wireless terminal time to scan for activity on another channel - e.g. for acquisition of another access point for handover purposes. See also subclause 7.2.1.

7.3.5 Residual errors

7.3.5.1 Detected errors

The error detection and correction capabilities of ATM stacks are typically low since they are designed for a basically reliable network. HIPERLAN/2 will make a best effort attempt to maintain the QoS of connections over time. However, link conditions and handover procedures may cause cells to be lost or delayed beyond their intended delivery time. In the latter case HIPERLAN/2 may discard such cells. Recovery of this kind of error condition is outside the scope of HIPERLAN/2 and belongs to the scope of the AAL specifications and/or application level recovery mechanisms.

7.3.5.2 Undetected errors

The residual undetected error rate of HIPERLAN/2 should be in the same range as that of a wired ATM system. This equates to an undetected DSDU error rate of $<5 \times 10^{-14}$.

HIPERLAN/2 shall meet these requirements through the use of the appropriate error detection mechanisms.

7.4 End user requirements

HIPERLAN/2 implementations are targeted at portable applications such as Notebooks and Personal Digital Assistants. This puts constraints of size (PCMCIA Type 2 or 3), cost (should be a fraction of the user device cost) and power consumption (because of host battery limitations).

These constraints may impact the functionality provided by the HIPERLAN/2 specification. For example, the wireless terminal adapter may have different modes of operation with different levels of power consumption. These modes of operation may have implications for the specification of the HIPERLAN/2 protocols, e.g. to support the signalling of mode transitions.

7.5 Security and privacy

7.5.1 General system security requirements

Users of HIPERLAN/2 systems may require protection of their transmissions from being intercepted by other users operating possibly co-located HIPERLAN/2 sub-networks. This requires the implementation of a data confidentiality service. The level of protection provided shall be consistent with the protection provided by wired systems that do not implement a data confidentiality service. Further, the cryptographic algorithm shall not be subject to export controls and therefore allowed for use.

ETSI has developed a cryptographic algorithm for HIPERLANs, the HIPERLAN Security Algorithm. This algorithm is designed to operate at 20+ Mbits/s and is available to ETSI members under a Confidentiality Agreement. The HIPERLAN/2 standard shall include functions for the selective use of encryption and for the synchronization of the use of cryptographic keys between wireless terminals of a HIPERLAN.

7.5.2 Network security

Network level security capabilities are addressed by ATM standards (in development); these are outside the scope of the HIPERLAN/2 Functional Standard.

7.6 Network management

The HIPERLAN/2 Functional Standard shall define Managed Objects for all the major functions and the monitoring of their performance.

8 HIPERLAN Type 3

HIPERLAN Type 3 (HIPERLAN/3) is a Remote Access version of HIPERLAN/2. It is intended for stationary and semi-stationary applications and provides a larger range - up to 5 km between wireless access points and wireless termination points. These remote access services are assumed to be deployed as license exempt systems by their owners to provide high speed access to fixed networks.

The following assumes that:

1) The increased range performance can be obtained by using directional antennas and by exploitation of digital signal processing technology to trade bit-rate for signal to noise ratio and therefore, range.

2) Directional antenna configurations will have implications for the specification of the MAC sublayer protocol.

3) The terminal devices will typically be stationary or slow moving - which removes the need to implement mobility support functions such as handover between access sub-networks or transceiver coverage areas.

8.1 Reference model

8.1.1 Services and capabilities

8.1.1.1 Services

HIPERLAN/3 shall provide or support the following services:

1) Connection set-up with parameter negotiation for QoS consistent with ATM service CBR, VBR-RT, VBR-NRT, ABR, UBR. Outgoing and incoming connections shall be supported.

2) Clearing of incoming connections and outgoing connections.

3) Unit data transfer [= ATM cell with Loss Priority Indication].

NOTE: Unit Data transfer comprises both Request (= transmit) and Indication (= receive) primitives.

8.1.1.2 Capabilities

HIPERLAN/3 shall provide the following capabilities:

1) Traffic management within each access subnetwork to maximize adherence to QoS parameters established at connection set-up.
2) Association of wireless termination points to access points in support of establishing ATM connections.
3) Informing the ATM switch that hosts an access subnetwork of the changes in the population of associated termination points.
4) Monitoring of radio conditions for informing user devices and the hosting ATM switch interworking unit of the prevailing radio conditions and traffic loads.
5) Switching connections between access points to provide back-up and load balancing. This is for further study.

8.1.2 Layer architecture

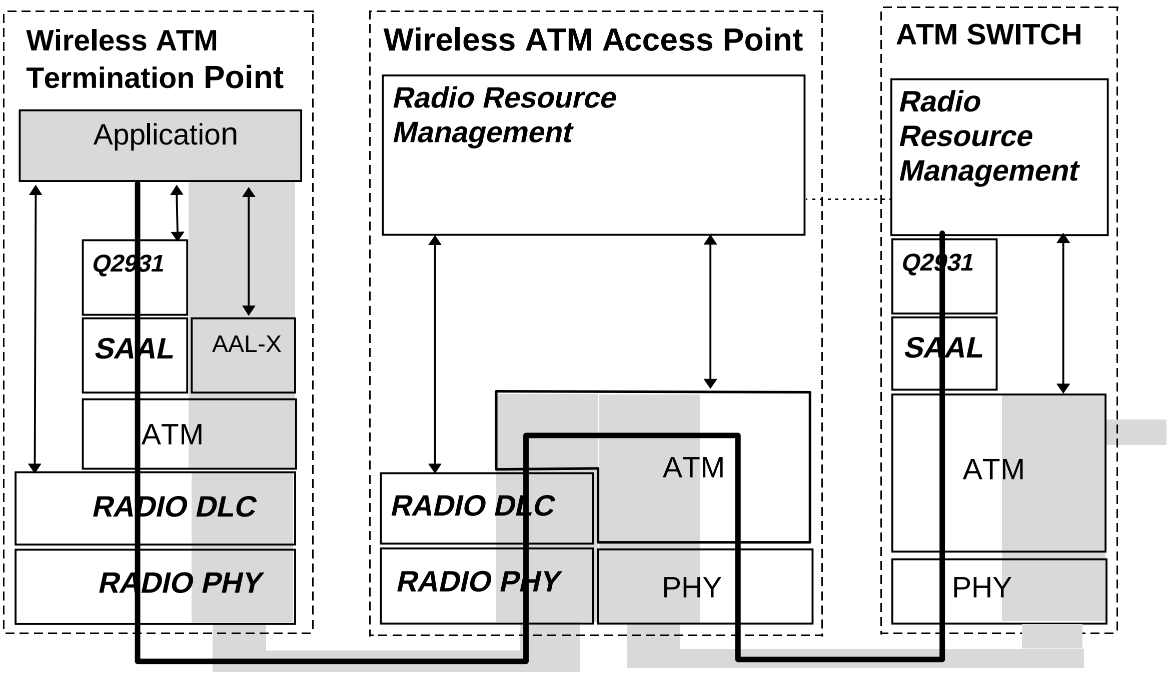

Figure 6: HIPERLAN/3 layer architecture

The dark lines indicate call control flows, the dashed lines special protocols between the three system elements, the grey band indicates user data flow. The thin black lines show the "off stack" control interfaces that allow user provided functions to control Radio DLC functions like (DLC) connection set-up and clearing.

This configuration gives full transparency at the ATM layer and therefore this architecture supports all existing and new types of ATM adaptation layers (AAL-X in figure 6) to the extend that these maintain compatibility with the existing ATM service definitions and protocol specifications.

The Radio DLC layer contains two sublayers: a Medium Access Control sublayer (MAC) and a Logical Link Control sublayer (LLC).

The MAC sublayer implements a service policy that takes into account such factors as channel quality, number of terminal devices and medium sharing with other access sub-networks.

The LLC sublayer maintains the quality of service on a virtual circuit basis. Depending on the type of service provided and channel quality, capacity and utilization, the LLC layer will implement a variety of means including FEC, ARQ and flow pacing to optimize the service provided to the (DLC) user.

NOTE 1: Within the ATM community, Generic Flow Control is being discussed - this may impact the functionality of the DLC layer and its service definition.

NOTE 2: Usage Parameter Control is an optional capability of ATM systems that may have impact on the specification of the Radio DLC layer and on the access point behaviour.

8.1.3 Interworking

HIPERLAN/3 Interworking requirements include:

1) Interworking at the ATM layer so as to provide a transparent service to the ATM service users; this includes possible extension of ITU-T Recommendation Q.2931 [4] for signalling and connection set-up and releasing functions.
   The extensions to ITU-T Recommendation Q.2931 [4] are outside the scope of HIPERLAN/3; these specifications are expected to be developed by the ATM Forum.

2) Interworking between the access point and the ATM switch Radio Resource management functions in support of connection establishment and QoS management.

8.1.4 Addressing

There are no specific addressing considerations; HIPERLAN/3 may use abbreviated addressing of some kind in order to reduce protocol overhead.

8.1.5 Reference model

The HIPERLAN/3 reference model identifies the following reference points:

Reference point H3.0 is a service interface which is defined in terms of abstract services and parameters for the User, Control and Management planes.

Reference point H3.1: defines the interface between the fixed network and the wireless ATM termination point. It is an interoperability interface that includes the following protocol definitions:

- The air interface protocol between the wireless terminal adapter and the access point. It includes the DLC protocol that supports transparent ATM transport (User, Control and Management plane traffic).

- The control plane signalling protocol between the ATM switch and the wireless ATM termination point. It includes the protocol for user registration and connection set-up and -releasing. Note that this interface may also be required to support alternate call routing in case of access point failure. This protocol is carried over the air interface protocol.

- The standard ATM user plane protocol.

Reference point H3.2: the interface between the access point and the ATM Switch and its management and control functions. It is an interoperability interface that includes the following specifications:

- The protocol that describes the interactions between the access point and the ATM Switch for the establishment and releasing of connections and for capacity management purposes. Note that this interface may also be required to support alternate call routing in case of access point failure.

- The standard ATM PHY user plane protocol.

NOTE: The access point may be considered to consist of one or more access point transceivers connected to a single access point controller. The interface between these two elements would not be visible.

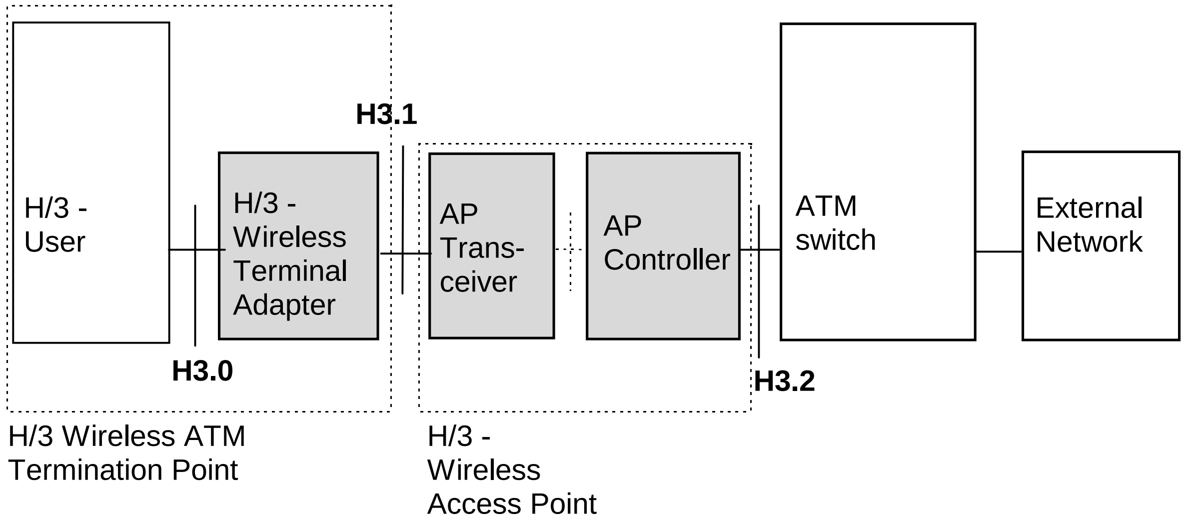

Figure 7: HIPERLAN/3 reference model

The HIPERLAN/3 standard will describe the mechanisms of the service Interface at the H3.0 reference point and the Air Interface Protocol at the H3.1 reference point. Specifications of other interfaces and functions are outside the scope of the HIPERLAN standards. In this case, the ATM Forum is the expected source of the other specifications.

8.2 Mobility support

HIPERLAN/3 shall support stationary and semi-stationary applications.

8.3 Requirements imposed on radio sub-system

8.3.1 Range

Up to 5 km over uncluttered terrain and with a free line of sight path between the Access Point and the Wireless Termination Point.

8.3.2 Data rate

HIPERLAN/3 shall provide a data rate at the air interface capable of supporting at least 30 K ATM cells/sec/termination point in a typical remote access environment.

8.3.3 Capacity

The capacity in terms of bits/s/hect of a HIPERLAN/3 network is limited by the number of RF channels available and the loading of these channels by HIPERLAN/3 networks operating in radio range of each other. The use of directional antennas will improve medium re-use significantly over HIPERLAN/2 and therefore result in significantly higher capacity figures and therefore a lower demand of RF spectrum.

Further, the actual capacity of a HIPERLAN/3 system depends on the protocol overhead, on the ratio between protocol overhead and typical traffic payload size and on the effective channel isolation.

8.3.4 QoS, user date rate, transfer latency transfer delay variance

When operating in an environment that does not vary, HIPERLAN/3 systems shall be able to maintain the data rate and QoS values of connections established at connection set up. For the applicable QoS parameters, see ITU-T Recommendation I.356 [9] and equivalent ATM Forum documents. The following values are provided as guidelines for the Cell Transfer Delay and Cell Delay Variance:

1) Cell Transfer Delay: < 5 msec.

2) Cell Delay Variance: < 1 msec.

These figures may not be realizable under all conditions and for all service categories.

Since cell transfer delay and cell delay variance accumulate along a communications path, the 5 msec is a reasonable target value that allows additional delay in other network components.

8.3.5 Residual errors

8.3.5.1 Detected errors

The error detection and correction capabilities of ATM stacks are typically low since they are designed for a basically reliable network. HIPERLAN/3 will make a best effort attempt to maintain the QoS of connections over time. However, link conditions may cause cells to be lost or delayed beyond their intended delivery time. In the latter case HIPERLAN/3 may discard such cells. Recovery of this kind of error condition is outside the scope of HIPERLAN/3 and belongs to the scope of the AAL specifications and/or user application mechanisms.

8.3.5.2 Undetected errors

The residual undetected error rate of HIPERLAN/3 should be in the same range as that of a wired ATM system. This equates to an undetected DSDU error rate of $<5 \times 10^{-14}$.

HIPERLAN/3 shall meet these requirements through the use of the appropriate error detection and recovery mechanisms.

8.4 End user requirements

As the applications of HIPERLAN/3 are typically between buildings rather than within buildings, device size and antenna size are less important than cost and reliability under adverse weather conditions.

It is noted that local regulations may impose limits on antenna size, mounting and appearance. However, these constraints are outside the scope of the HIPERLAN/3 Functional Specification.

Further, the energy levels within the antenna beam shall fall within the legal safety limits for the exposure of human beings to RF microwave energy.

8.5 Security and privacy

8.5.1 General system security requirements

Users of HIPERLAN/3 systems may require protection of their transmissions from being intercepted by other users operating possibly co-located HIPERLANs. This requires the implementation of a data confidentiality service that operates on a per Termination Point basis. The level of protection provided shall be consistent with the protection provided by wired systems that do not implement a data confidentiality service. Further, the cryptographic algorithm shall not be subject to export controls and therefore allowed for world-wide use.

ETSI has developed a cryptographic algorithm for HIPERLAN/1: the HIPERLAN Security Algorithm. This algorithm is designed to operate at 20+ Mbits/s and is available to ETSI members under a Confidentiality Agreement. The HIPERLAN/3 standard shall include functions for the selective use of encryption and for the synchronization of the use of cryptographic keys between wireless terminals of a HIPERLAN.

8.5.2 Network security

Network level security capabilities are addressed by ATM standards (in development); these are outside the scope of the HIPERLAN Functional Standards.

8.6 Network management

The HIPERLAN/3 Functional Standard shall define Managed Objects for all the major functions and capabilities as well as their performance monitoring.

9 HIPERLAN Type 4

HIPERLAN Type 4 (HIPERLAN/4) shall provide very high data rate (up to 155 Mbits/s) links for infrastructure applications. A combination of these links may be used to connect ATM network nodes in a variety of topologies.

HIPERLAN/4 links shall support:

1) Wireless connection between two ATM networks.

2) Wireless connection between an ATM network and HIPERLAN/2 or /3 access point.

3) Wireless connection between an ATM network and an ATM terminal.

The scope of the HIPERLAN/4 specification will be limited to Physical and DLC layers and the supporting capabilities required to implement such point-to-point links.

9.1 Reference model

9.1.1 Services and supporting capabilities

9.1.1.1 Services

HIPERLAN/4 shall support the following services:

1) Connection set-up with parameter negotiation for QoS consistent with ATM service CBR, VBR-RT, VBR-NRT, ABR and UBR. Outgoing and incoming connections shall be supported.

2) Release of incoming connections and outgoing connections.

3) Unit data transfer [= ATM cell with Loss Priority Indication]

NOTE: Unit Data transfer comprises both Request (= transmit) and Indication (= receive) primitives.

9.1.1.2 Capabilities

HIPERLAN/4 shall support the following capabilities:

1) Establishment of links between any pair of link terminating nodes within radio range.

2) Traffic management within a connection to maximize adherence to QoS parameters established at connection set-up.

3) Informing the ATM switch or host system about the available connections and their capacity.

NOTE: Re-routeing of traffic flows to assure continuous connectivity in case of node failure or link interruptions due to environmental factors is outside the scope of the HIPERLAN/4 specification.

9.1.2 Layer architecture

Figure 8 gives the layer architecture for HIPERLAN/4.

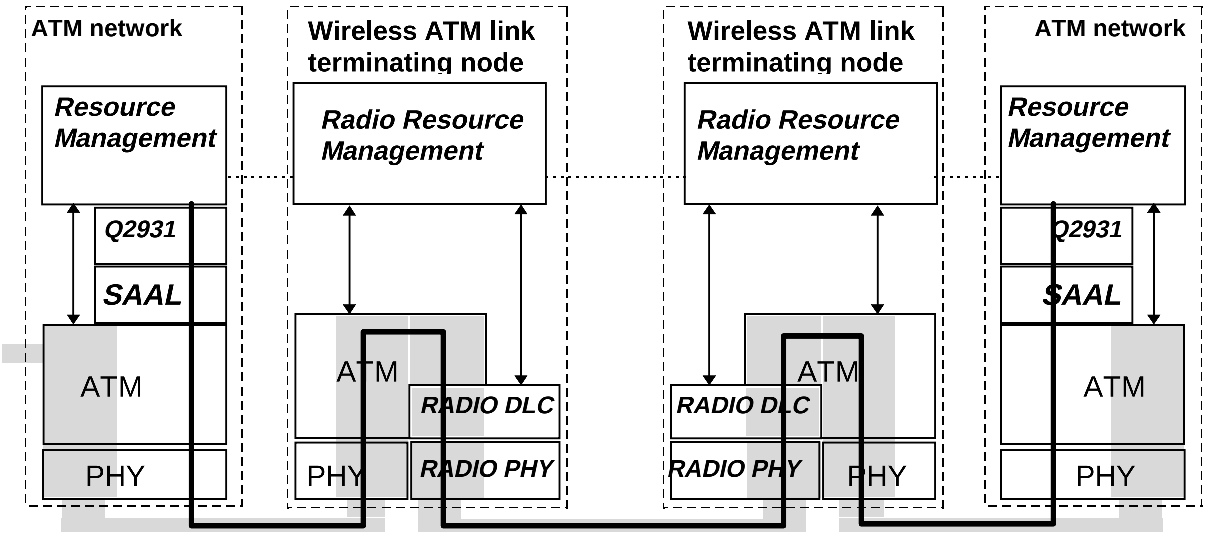

Figure 8: HIPERLAN/4 Layer architecture

The dark lines indicate call control flows, the dashed lines special protocols between the system elements, the grey band indicates user data flow. The thin black lines show the "off stack" control interfaces that allow user provided functions to control Radio DLC functions like (DLC) connection set-up and releasing.

9.1.3 Interworking

The interworking specification for HIPERLAN/4 is assumed to be the P-NNI specification.

9.1.4 Addressing

The addressing of the link terminating nodes is a local matter. HIPERLAN/4 should be transparent to ATM addressing issues.

9.1.5 Reference model

Figure 9 depicts the HIPERLAN/4 reference model.

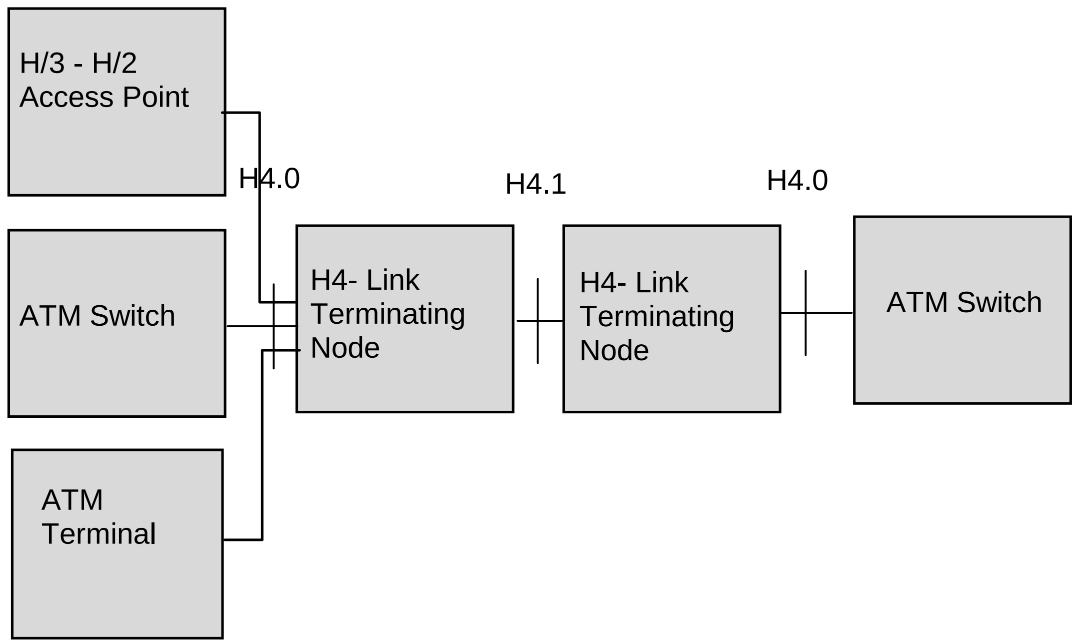

Figure 9: HIPERLAN/4 reference model

The H4.0 Reference Point describes an interface that can be the User Network Interface (UNI), Private Network-to-Network Interface (P-NNI) or both.

The H4.1 Reference Point describes an internal HIPERLAN/4 air interface that supports transparent ATM transport. This interface is an inter-operability interface.

9.2 Mobility support

Mobility support is not required.

9.3 Requirements imposed on radio sub-system

9.3.1 Range

Up to 150 m. This requires (highly) directional receive antennas.

NOTE: The use of such antennas shall be negotiated with the ERC.

9.3.2 Data rate

HIPERLAN/4 shall provide a data rate at the air interface capable of supporting at least 180 K ATM cells/sec/terminal in a typical indoor environment.

9.3.3 Capacity

The net capacity of a single infrastructure subnetwork is determined by such factors as the number of interworking points, the protocol overhead, the re-use of the same link for multiple traffic flows, the raw bit rate offered to the external networks or terminals and the spectrum re-use.

At 17 GHz highly directional antennas can be used. Antenna openings of 12° would allow more than 1 500 % reuse (assuming that every other antenna can support an independent channel). In this case, radio channels used for HIPERLAN/4 sub-networks can achieve very high capacity figures.

9.3.4 QoS, user data rate, transfer latency and transfer delay variance

When operating on an channel that does not vary, HIPERLAN/4 systems shall be able to maintain the data rate and QoS values of connections established at connection set up. For the applicable QoS parameters, see ITU-T Recommendation I.356 [9] and equivalent ATM Forum documents. The following values are provided as guidelines for the Cell Transfer Delay and Cell Delay Variance:

1) Cell Transfer Delay: < 5 msec

2) Cell Delay Variance: < 1 msec

These figures may not be realizable under all conditions and for all service categories.

Since cell transfer delay and cell delay variance accumulate along a communications path, the above figures are reasonable target values that allows additional delay in other network components.

9.3.5 Residual errors

9.3.5.1 Detected errors

The error detection and correction capabilities of ATM stacks are typically slow since they are designed for a basically reliable network. HIPERLAN/4 will make a best effort attempt to maintain the QoS of connections over time. However, link conditions and handover procedures may cause cells to be lost or delayed beyond their intended delivery time. In the latter case HIPERLAN/4 may discard such cells. Recovery of this kind of error condition is outside the scope of HIPERLAN/4 and belongs to the scope of the AAL specifications.

9.3.5.2 Undetected errors

The residual undetected error rate of HIPERLAN/4 should be in the same range as that of a wired ATM system. This equates to: an undetected DSDU error rate of $<5 \times 10^{-14}$.

HIPERLAN/4 shall meet these requirements through the use of the appropriate error detection and recovery mechanisms.

9.4 End user requirements

As the applications of HIPERLAN/4 are typically within buildings, device size, antenna and appearance are significant issues. However, these constraints are outside the scope of the HIPERLAN/4 specifications.

Further, the energy levels within the antenna beam shall fall within the legally safety limits for the exposure of human beings to RF microwave energy.

9.5 Security and privacy

9.5.1 General system security requirements

Users of HIPERLAN/4 systems may require protection of their transmissions from being intercepted by other users operating possibly co-located HIPERLANs.

This requires the implementation of a data confidentiality service that operates on a per connection basis. The level of protection provided shall be consistent with the protection provided by wired systems that do not implement a data confidentiality service. Further, the cryptographic algorithm shall not be subject to export controls and therefore allow world-wide use.

The HIPERLAN/4 standard shall include functions for the selective use of encryption and for the synchronization of the use of cryptographic keys between nodes of a HIPERLAN.

9.5.2 Network security

Network level security capabilities are addressed by ATM standards (in development); these are outside the scope of the HIPERLAN Functional Standards.

9.6 Network management

The HIPERLAN/4 Functional Standard shall define Managed Objects for all the major functions and capabilities as well as their performance monitoring.

10 Conformance, interoperability testing and type approval

Type Approval shall be according to the accepted regulatory procedures. The basis for testing against applicable spectrum utilization parameters shall be an EN developed for this purpose. Upon application for Type Approval, the supplier shall declare conformance with an applicable HIPERLAN Functional Specification and supply a completed PICS (Protocol Implementation Conformance Statement) questionnaire to support this declaration.

Annex A: Summary of ATM Services

In any system capacity is, ultimately, a scarce resource that shall be shared between its users. In ATM systems, the sharing method is arbitration by the switch as opposed to the random sharing method exemplified by Ethernet. In order for an ATM switch to be able to play its role as service arbitrator, it shall know the needs of its terminal nodes. ATM terminal nodes request services in terms of destination(s), bit rate(s) and Quality of Service (**QoS**) parameters. If the request can be granted without impacting the services already committed to, the switch will grant the request. In that case, the node can expect to obtain the requested services — provided it does not exceed its requests — until it changes its requested service level. The switch would deny new users access if that access would cause degradation of the services already granted to existing users.

Based on the QoS parameters, the five ATM service classes are:

- ***Constant Bit Rate (CBR)*** - the bit rate is constant during the connection; the switch services the node at a rate that is consistent with the bit rate agreed during connection set-up. This service is well suited to conventional digital voice and video traffic; it is sometimes referred to as Circuit Emulation.

- ***Variable Bit Rate - Real-Time (VBR-RT)*** - the bit rate varies between zero and a peak bit rate as agreed at connection set-up. In addition the terminal advertises a sustained, or average cell rate and a maximum burst size; i.e. the maximum time during which the source generates cells at the peak rate. This service makes more effective use of the switch capacity as it allows some statistical multiplexing to occur between variable bit rate sources. The delay is bounded which makes this type of service especially suitable for compressed voice or video transmission.

- ***Variable Bit Rate - Non Real-Time (VBR-NRT)*** - is essentially VBR-RT, except that there is no guaranteed delay bound. This type of service would be appropriate for data traffic, which has less stringent delay requirements but which still needs throughput guarantees. An example is LAN interconnection. Typical use is for connection-oriented traditional data traffic (such as X.25), and for connectionless traditional data traffic (such as TCP/IP).

- ***Available Bit Rate (ABR)*** - ABR is like VBR-NRT but with only a minimum bandwidth guarantee. The cell loss probability will still be bounded, however. This service allows an ATM system to fill its channels to the maximum capacity when there are periods where CBR and VBR traffic are low. The source terminal can negotiate a minimum rate. The network will guarantee cell transfer at this minimum rate and provide additional capacity on a best effort basis. This service would typically be used to carry non time-critical computer data traffic, e.g. to feed a Web browser. For this application, users want an acceptable response time as a basic service, plus anything else that the network can offer in addition.

- ***Unspecified Bit Rate (UBR)*** - is a best effort service without any performance guarantees. Typical use is for non-real-time applications, such as file transfer, backup traffic and e-mail.

These traffic classifications have been recommended by the ATM Forum. Its latest User Network Interface specification (UNI 4.0 [8]), has been hailed as the standard that will allow ATM to really deliver on its promises. According to UNI 4.0 [8], CBR service will be supported by AAL1, while all other services will use AAL5.

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