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A Comparison of IEEE 802.11a and HIPERLAN/2 Wireless Networks

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Introduction

Wireless Local Area Networks (WLANs) provide wideband wireless connectivity without the need for cable installation. WLANs can be used in different environments such as home, public, corporate, industry and government. The worldwide demand for broadband wireless communications for multimedia applications supporting higher data rates has prompted standards organizations to develop new standards to promote compatibility and interoperability between competing technologies. A prime example is the use of spread spectrum cordless phones and 802.11b devices in the 2.4GHz band. The reality is the 2.4 GHz band is, in high population areas, too congested for continued expansion of WLANs. The next band above 2.4 GHz available for WLANs is the 5 GHz band.

There are presently two standards for wireless networking, which have been developed for the 5 GHz band. They are the European Telecommunications Standards Institute (ETSI) Project Broadband Radio Access Networks (BRAN) HIgh PERformance Local Area Networks – Type 2 (HIPERLAN/2) and the Institute of Electrical and Electronics Engineers (IEEE) 802.11a. These standards define protocols in the Open Systems Interconnection (OSI) physical and link layers. They support multiple transmission modes (providing data rates up to 54 Mbps where channel conditions permit) and offer the throughput necessary for multimedia applications and high speed Internet access.

This Technical Note compares and contrasts the HIPERLAN/2 and 802.11a standards and identifies worldwide implementation issues. It will also address harmonization issues between the two standards. The architecture for the two standards is depicted in Figure 1.

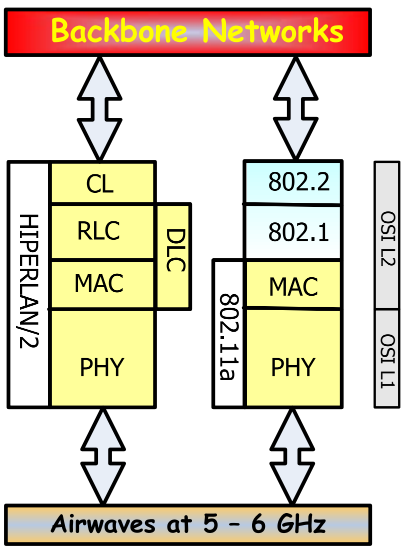

Figure 1. Layer Architecture for HIPERLAN/2 and 802.11a

The HIPERLAN/2 standard is defined such that there are independent Physical (PHY), Data Link Control (DLC), and Convergence Layers (CL). The DLC sublayer is composed of the Medium Access Control (MAC) and Radio Link Control (RLC) sublayers. The Convergence Layer (CL) provides for inter-facing with:

- Ethernet
- Point-to-Point Protocol – Internet Protocol (PPP-IP)
- Asynchronous Transfer Mode (ATM)
- Universal Mobile Telecommunications System (UMTS)
- IEEE 1394 infrastructure.

IEEE 802.11a similarly defines independent PHY and MAC sublayers. The IEEE 802.11a network is such that the MAC sublayer is contained within the Data Link Layer (DLL) and interfaces to the backbone network through the 802.1 Bridging and 802.2 Logical Link sublayers. Note that 802.1 and 802.2 are not part of the 802.11a standard.

802.11a and HIPERLAN/2 Physical Layer

One of the major issues for all Radio Frequency (RF) communications has been the lack of worldwide agreements on the use of unlicensed spectrum. US equipment manufacturers recognized the 5 GHz spectrum range was relatively under-utilized and saw this as an opportunity to offer a new product. As a result, the IEEE 802.11a standard was developed. This standard proposed a 5 GHz PHY layer and provided for an increase in operational speed from the 802.11b standard of 11Mbps to 54 Mbps.

The physical layer for both standards provides the interface to the airwaves for wireless networks. They are similar and use Orthogonal Frequency Division Multi-plexing (OFDM) as the coding scheme. OFDM is used to reduce frequency selective fading and to randomize the burst errors. The PHY layer breaks down the packets from the link layer into OFDM symbols for transmission. Data packets from the link layer go through encoding and interleaving before they are transmitted. Convolution encoders are used by both standards to enable error detection and correction. Interleaving is used to minimize burst errors. The encoded and interleaved data are mapped into data symbols according to either a BPSK, QPSK, 16-QAM or 64-QAM[1] modulation scheme.

Each standard selects its operational modes in the network design process by the link adaptation scheme. The exact mechanism of this process is not specified in either standard. Table 1 shows the modulation

[1] Binary Phase Shift Keying (BPSK), Quaternary Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM)

schemes and coding rates common to both standards.

Modulation Scheme	Coding Rate	Physical Data Rate	Data Bits per Symbol
Both Standards			
BPSK	1/2	6 Mbps	24
BPSK	3/4	9 Mbps	36
QPSK	1/2	12 Mbps	48
QPSK	3/4	18 Mbps	72
16-QAM	3/4	36 Mbps	144
HIPERLAN/2 Only			
16-QAM	9/16	27 Mbps	108
802.11a Only			
16-QAM	1/2	24 Mbps	96
64-QAM	2/3	48 Mbps	192
Both standards (optional)			
64-QAM	3/4	54 Mbps	216

Table 1. Modulation Schemes and Coding Rates for HIPERLAN/2 and 802.11a

A bit scrambler is used to prevent long runs of ones or zeroes which could impact the synchronization process. The difference between the two standards is in the initialization of the scrambler.

MAC Sublayer

Figure 1 identifies the MAC sublayer as part of the link layer in the 802.11a architecture. In HIPERLAN/2, the MAC sublayer is part of the DLC sublayer. The most significant differences between IEEE 802.11a and HIPERLAN/2 standards occur in the MAC sublayer.

Each standard specifies a preamble in the MAC sublayer which is used to alert network devices that a data frame is coming. The preamble provides synchronization through specific training symbol sequences. The training symbols used for channel estimation (long training symbols) are the same, while those provided for synchronization (short training symbols) are different.

The MAC sublayer in HIPERLAN/2 is based on a Time Division Duplex/Time Division Multiple Access (TDD/TDMA) approach. It uses a time frame with a period of 2 ms. Time slots are allocated dynamically depending on the need for transmission resources. 802.11a uses a distributed MAC sublayer protocol based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).

HIPERLAN/2 MAC Sublayer

HIPERLAN/2 MAC sublayer frame structure is shown in Figure 3. It comprises time slots for Broadcast Control (BCH), Frame Control (FCH), Access Feedback Control (ACH), and data transmission in three different phases: Downlink (DL), Uplink (UL), and Directlink (DiL) (data phases are allocated dynamically depending on the need for transmission resources). And finally, the Random Access Channel (RCH), used by mobile terminals to request capacity from the AP.

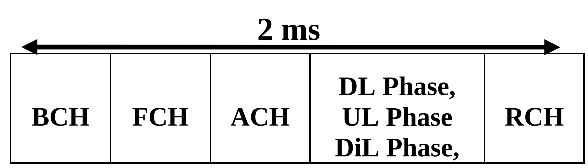

Figure 3. The HIPERLAN/2 MAC Frame Structure

The downlink, uplink and direct link phases consist of two types of Protocol Data Units (PDUs): long and short. Long PDUs (shown in Figure 4) have a size of 54 bytes and contain control or user data. The payload is 49.5 bytes and the remaining 4.5 bytes are used for the PDU Type (2 bits), a Sequence Number (SN) (10 bits) and Cyclic

Redundancy Check (CRC) (3 bytes). Long PDUs are referred to as the Long Transport Channel (LCH).

54 bytes

PDU Type	SN	Payload	CRC
(2 bits)	(10 bits)	(49.5 bytes)	(3 Bytes)

Figure 4. Format of the Long PDUs

Short PDUs contain only control data and have a size of 9 bytes. The 9-byte payload consists of PDU Type (4 bits), Information (52 bits), and the CRC (2 bytes). They may contain resource requests, Automatic Retransmission reQuest (ARQ) messages, etc., and they are referred to as the Short Transport Channel (SCH). Traffic from multiple connections to/from one Mobile Terminal (MT) can be multiplexed onto one PDU train, which contains both long and short PDUs.

HIPERLAN/2 was developed in Europe and addressed the issue of interference with other devices already in use in the 5GHz range. It added two protocols in the RLC sublayer to address interference issues. These protocols are Dynamic Frequency Selection (DFS) and Transmission Power Control (TPC).

When DFS is employed, an Applications Processor (AP) listens to see if the spectrum is in use before it transmits on a channel. Detecting the presence of spectrum usage is based on a common test, European Telecommunications Standards Institute (ETSI) 301-893.

TPC enables Information Technology (IT) managers to control the AP output power, thus controlling the cell size. Europe has imposed additional power restrictions for unlicensed devices in and around airports. In Europe, APs cannot transmit higher than 50 milliwatts (mW) to reduce the chance of interference with this equipment.

IEEE 802.11a MAC Sublayer

IEEE 802.11a uses a distributed MAC protocol based on CSMA/CA. Figure 5 shows the format of a complete packet PDU (PPDU) in 802.11a, including the preamble, header and Physical Layer Service Data Unit ((PSDU) or payload). 802.11a networks use a packet structure and not a time frame like HIPERLAN/2.

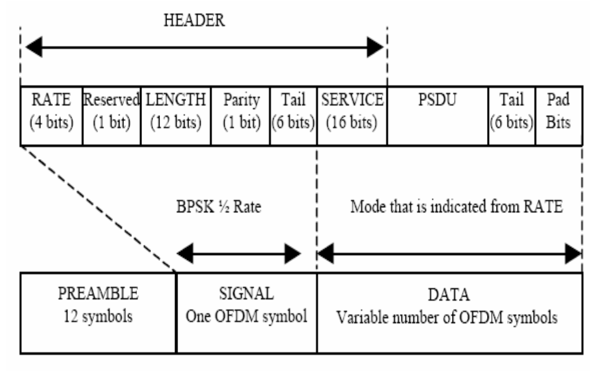

Figure 5. 802.11a Packet PDU (PPDU) Format

In 802.11a networks, mobile terminals sense the medium for traffic. If the medium is idle the MT can start transmitting the packet. Otherwise the transmission is deferred and a wait process begins. Once the wait time has expired, the terminal can access the medium again.

802.11a is an Acknowledge/Negative Acknowledge (ACK/NAK) system in that a positive acknowledgement is used to indicate that a packet has been successfully received. If this acknowledgement is not received, the terminal will retransmit the packet.

The header contains information about the transmission rate, length of the payload, a parity bit, 6 zero tail bits, and 16 service bits. The header is always transmitted using the lowest rate transmission mode in order to ensure robust reception. Hence, it is mapped onto a single BPSK modulated OFDM symbol.

The rate field conveys information about the type of modulation and the coding rate used for the rest of the packet. The length field takes a value between 1 and 4095 and specifies the number of bytes in the PSDU. The Service field is used to initiate the scrambler process.

Differences Between HIPERLAN/2 and 802.11a MAC Sublayers

Differences between the two standards are in response to different requirements. 802.11a was written to be complimentary to the IEEE 802 series of Local Area Network/Metropolitan Area Network (LAN/MAN) standards. 802 series standards focus on Ethernet and Token Ring networks and assume that most WLANs will be extensions of these types of networks.

The HIPERLAN/2 defines in the OSI link layer additional protocols to enable interfacing with other high-speed networks, including Third Generation (3G) cellular, ATM, or Internet Protocol based networks. This is accomplished in the convergence sublayer. This can be a real advantage when integrating wireless LANs with cellular systems and other wide area networks.

802.11 networks treat all data the same regardless of the type of data. On the other hand, HIPERLAN/2 can recognize and prioritize the transmission of a variety of information types such as voice, video, and data. This allows Quality of Service (QoS) protocols to be implemented for different data usage.

Both 802.11a and HIPERLAN/2 claim maximum data rates of 54Mbps, but this doesn't represent the actual rate of information flow between the station and the access point. The true maximum throughput differs depending on several factors: packet or frame size, coding rate, overhead data, and collisions.

MAC Sublayer Harmonization

When 802.11a standard was developed, the IEEE committee did not account for how the 5 GHz spectrum was being used around the world. Figure 6 shows the power restrictions defined by the ITU for available unlicensed bandwidth segments in the 5-6 GHz spectrum.

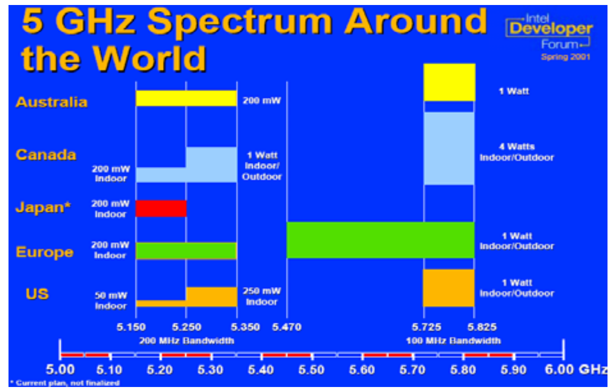

Figure 6. Power Limits in the Unlicensed 5 GHz Band

The IEEE and ETSI are working together toward harmonizing 802.11a with HIPERLAN/2. The 802.11h Task Group (802.11h) was assigned the task of amending the 802.11 1999 standard to include the DFS and TPC Protocols. On September 11, 2003 the IEEE Standards Board approved the 802.11h standard titled "IEEE Standard for Information Technology - Telecommunications and Information Exchange between Systems - Local and Metropolitan Area Networks-Specific Requirements Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Spectrum and Transmit Power Management Extensions in the 5 GHz Band in Europe". The abstract of the standard states "This amendment specifies the extensions to IEEE 802.11™ for wireless local area networks (WLANs) providing mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in the

5 GHz band in Europe.” DFS is required by all countries in the EU by the end of 2004.

Similarly, on September 23, 2004, the IEEE Standards Board approved 802.11j which amends “…Part 11 for Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: 4.9 GHz - 5 GHz Operation in Japan”. The approval of these standards opens the door to wider deployment of 802.11a in Europe and Japan.

The other major difference between 802.11a and HIPERLAN/2 is that HIPERLAN/2 currently supports QoS at the MAC sublayer. The current 802.11a MAC has no means of differentiating traffic streams or sources. All data is treated equally. Currently, the IEEE has assigned the task of amending the 802.11 standard to include QoS to the 802.11e Working Group (WG). Task Group (TG) 802.11e was unable to get the standard included into the agenda for the most recent IEEE Standards Board Meeting. This standard is almost completed and as such, many manufacturers have stated they will begin to include the functionality of this standard in their equipment in late 2004 to 2005.

Conclusions

Table 2 shows a side-by-side comparison of the major features of each standard. The HIPERLAN/2 and 802.11a standards are similar in many aspects. However, they differ substantively in the MAC layer as well some differences in the PHY layer. At present, there is a great deal of effort on-going within the IEEE 802 Committee to harmonize these two standards as well as to make IEEE 802.11a compatible in other countries such as Japan. Within the last year, IEEE 802.11h has been approved by the IEEE, which harmonizes 802.11a with HIPERLAN/2. IEEE 802.11j has also been approved, which harmonizes 802.11a for use within Japan.

It can be concluded that:

- 802.11a and HIPERLAN/2 PHY layers are compatible
- 802.11a and HIPERLAN/2 should be able to exchange data supporting an Ethernet environment
- 802.11h supplement has been approved. This opens the door to potential wider deployment of 802.11a networks within Europe.
- 802.11a is currently working to develop QoS, through the 802.11e WG, to support the features that HIPERLAN/2 already has.

Feature of the Standard	802.11a	HIPERLAN/2
Support for data rates of 54 Mbps	Yes	Yes
Support Dynamic Frequency Selection	Yes	Yes
Provide Controls for Transmit Power	Yes	Yes
Interface with Ethernet and Token Ring Networks	Yes	Yes (Ethernet Only)
Based on Ethernet using CSMA/CA	Yes	No
Based on Time Division Multiplexing	No	Yes
Can Interface with 3G Cellular Networks	No	Yes
Can Interface with ATM Networks	No	Yes
Support QoS for different connections like voice and video	No	Yes

Table 2. Comparison of 802.11a and HIPERLAN/2 Standards

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