IEEE P802.11
Wireless LANs

Title

ITU-R Activity JRG 8A-9B

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Abstract

This is a paper that was submitted to the ITU-R to provide input on Broadband RLAN characteristics.

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Rapporteur's Report, Task 4*

CHARACTERISTICS OF BROADBAND RADIO LOCAL AREA NETWORKS (RLANs)

(Questions ITU-R 212/8 and 142/9)

considering

a) that broadband RLANs will be widely used for semi-fixed (transportable) and portable computer equipment for a variety of broadband applications;

b) that broadband RLAN standards currently being developed will be compatible with current wired LAN standards

c) that it is desirable to establish guidelines for broadband RLANs in various frequency bands

d) that the above guidelines not limit the effectiveness of broadband RLANs but be used to enhance their development

e) that broadband RLANs should be implemented with careful consideration to compatibility with other radio applications

r*ecommends*

1 that for guidance on some proposed methods of multiple access and modulation techniques refer to Table 1;
2 that for guidance on developing broadband RLAN applications refer to Table 2;
3 that for guidance refer to the characteristics of broadband RLANs in the Annex A to this Recommendation
4 that for guidance on modulation schemes using OFDM for broadband RLANs refer to ANNEX B

* **T**he intent of this document is to provide proposed draft Recommendations on broadband RLANs to JRG 8A-9B.

TABLE 1

Frequency Band	Access Method	Modulation Method
UHF	CSMA/CA, FDMA, TDMA, CDMA (direct sequence spread spectrum)	CCK (Complementary Code Keying)
SHF	CSMA/CA, FDMA, TDMA-FDD, TDMA/EY-NPMA CDMA (direct sequence spread spectrum)	64 QAM , 16QAM-OFDM, 8-PSK-OFDM QPSK-OFDM BPSK-OFDM, GMSK/FSK

Broadband RLAN Terms

The following terms are used to describe the characteristics of RLANs:

1. Access method- Scheme used to provide multiple access to a channel.
2. Modulation- The method used to put information on an RF carrier
3. Bit rate- The rate of transfer of bit information from one network device to another.
4. Frequency Band– Nominal operating spectrum of application
5. Channelization- Bandwidth of each channel and number of channels that can be contained in the RF Bandwidth allocation.
6. Tx power (Transmitter power)- RF power in watts produced by the transmitter.

Current broadband RLAN applications standards either complete or in development and characteristics:

TABLE 2 Broadband RLAN Applications

Network standard	IEEE Project 802.11b	IEEE 1 Project 802.11a	ETSI BRAN HIPERLAN 1 ETS 300-652	ETSI BRAN 1 HIPERLAN 2 DTR/BRAN-010002 V0.1.3 (1998-09)
Access Method	CSMA/CA, CDMA	CSMA/CA	TDMA/EY-NPMA	TDMA/TDD
Modulation	CCK , Complementary Code Keying 8 Complex Chip Spreading	64 QAM , 16-QAM-OFDM QPSK-OFDM BPSK-OFDM	GMSK/FSK	16-QAM-OFDM 8-PSK-OFDM QPSK-OFDM BPSK-OFDM
Data rate	1, 2, 5.5 & 11 Mbits/s	6, 12, 18, 24, 36, 48, 54 Mbits/s	23 Mbit/s	5, 14, 24, 36 Mbits/s
Frequency Band	2,400-2,483.5 MHz	5,150 to 5,250 MHz and 5,250 to 5,350 MHz and 5,725 to 5,825 MHz	5,150 to 5,300 Limited in some countries to 5,150 to 5,250 see note 3	5 GHz Band
Channelization	25/30 MHz spacing 3 channels	18 MHz Channel Spacing 4 channels in 100 MHz	23.5294 MHz 3 channels in 100 MHz and 5 channels in 150 MHz	25 MHz channel spacing is current working assumption
Tx power	Maximum Output Power, Geographic Location Compliance Document 1000 mW USA as per FCC 15.247 100 mW (EIRP) EUROPE ETS 300-328 10 mW/MHz JAPAN MPT ordinance for Regulating Radio Equipment, Article 49-20	5,150 to 5,250 MHz 200 mW EIRP in a 20 MHz channel. 5,250 to 5,350 MHz 1 W EIRP in a 20 MHz channel. 5,725 TO 5,825 MHZ 4 W EIRP IN A 20 MHz CHANNEL ALL ITEMS FROM FCC Amendment of the Commission's Rules to ET Docket No. 96-102 Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range RM-8653	Three different classes of power levels depending on country administration 1 Watt EIRP, 100 mW EIRP, 10 mW EIRP see note 4	1 W EIRP is assumed, depends on future regulations and administration
Sharing considerations	• CDMA (Code Division Multiple Access) allows orthogonal spectrum spreading. • CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) provides “listen before talk “ access etiquette	• OFDM (Orthogonal Frequency Division Multiplexing) provides low power spectral density. • CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) provides “listen before talk “ access etiquette		OFDM (Orthogonal Frequency Division Multiplexing) provides low power spectral density

1 IEEE 802.11a and ETSI BRAN HIPERLAN2 are working together to come up with a common physical layer.

2 WATM (Wireless ATM) and advanced IP with QoS (Ipv^, RSVP) are intended for use over ETSI BRAN HIPERLAN 2 physical transport.

3 Allocation of additional spectrum is under study within CEPT.

4 Some restrictions on max output power are under study in the band 5150-5250 MHz within CEPT.

ANNEX A

1 Introduction

At the March ‘98 meeting of Working Party 8A an additional Task was established for the Joint Rapporteurs Group 8A-9B. Task 4 was established to study the characteristics of Broadband

RLAN's relative to other systems that share the same spectrum. This contribution is an attempt to list those characteristics and provide current generic applications of broadband RLANs.

Emerging broadband RLAN standards will allow compatibility with wired LANs such as IEEE 802.3, 10BASE-T, 100BASE-T and 51.2 Mbit/s ATM at comparable data rates. Some broadband RLANs have been developed to be compatible with current wired LANs and are intended to function as an wireless extension of wired LANs using TCP/IP and ATM protocols. This will allow operation without the "bottle neck" that occurs with current wireless LANs. Recent bandwidth allocations by some administrations will help promote development of broadband RLANs.

A feature provided by broadband RLANs not provided by wired LANs is portability. New laptop and palmtop computers are very portable and have the ability when connected to a wired LAN to provide interactive services. However, when they are connected to wired LANs you lose the portability feature. Broadband RLANs allow portable computing devices to remain portable and operate at maximum potential

Private on-premise computer networks are not covered by traditional definitions of Fixed and mobile wireless access and should be considered separately. The nomadic user of the future will no longer be bound to a desk. Instead, they will be able to carry their computing devices with them and maintain contact with the wired LAN in the facility.

2 Characteristics of Broadband RLANs

Speeds of notebook computers and hand held computing devices are increasing steadily. Many of these devices are able to provide interactive communications between users on a wired network but sacrifice portability when connected. Multi-media applications and services require broadband communications facilities not only for wired terminals but also for portable and personal communications devices. Wired local area network standards, i.e. IEEE 802.3ab 1000BASE-T, are in development that will be able to transport multi-media applications. To maintain portability future wireless LANs will need to transport higher data rates. Broadband RLANs are generally defined as those that can provide data throughput greater than 2 Mbit/s.

The following are characteristics of Broadband RLANs:

2.1 Broadband RLANs may be either pseudo fixed as in the case of a desk top computer that may be transported from place to place or portable as in the case of a laptop or palm top working on batteries. Relative velocity between devices remains low. In warehousing applications RLANs may be used to maintain contact with lift trucks at speeds of up to 6 meters per second. RLAN devices are not generally designed to be used at automotive or higher speeds

2.2 Broadband RLANs are predominantly deployed inside buildings, in offices, factories, warehouses etc. The large scale average excess loss due to building attenuation is expected to be 15 dB or greater based on reported measurements. The majority of RLAN devices are expected to be deployed inside buildings

2.3 Broadband RLANs utilise low power levels as a result of the short distance nature of inside building operation. Power spectral density requirements are based on a basic service area of a single RLAN defined by a circle with a radius of about 40 meters. When larger networks are required, RLANS may be logically concatenated or bridged to form larger networks without increasing their composite power spectral density

2.4 Broadband RLANs , to achieve the coverage areas specified above, require a peak power spectral density of 12.5 mW/MHz in the 5 GHz operating frequency range. The required power spectral density is proportional to the square of the operating frequency. The large scale, average power spectral density will be substantially lower than the peak value.

2.5 Broadband RLAN devices share spectrum on a time basis and the maximum large scale aggregate RF power on-off activity ratio is estimated at less than 1%.

2.6 Broadband RLAN devices are normally deployed in high density configurations and use an etiquette such as "listen before talk" and dynamic channel assignment to facilitate spectrum sharing between devices.

2.7 Broadband RLANs are nearly always multipoint architecture. Multipoint applications commonly use omni-directional antennas. The multipoint architecture employs two system configurations:

2.7.1 Multipoint centralised system (multiple devices connecting to a central device or access point (AP) via a radio interface).

2.7.2 Multipoint non-centralised system (multiple devices communicating in a small area on an ad hoc basis).

2.8 Occasionally, fixed point to point devices are implemented between buildings in a campus environment. Point to Point systems commonly use directional antennas that allow greater distance between devices with a narrow lobe angle. This allows band sharing via channel reuse with a minimum of interference with other applications.

2.9 Broadband RLANs are not considered fixed wireless access (FWA) systems which normally use FS or MS allocated spectrum. Broadband RLANs are generally confined to a smaller service area and use different protocols. Spectrum allocation for broadband RLANs should be considered separate from these applications.

ANNEX B

PREFERRED MODULATION TECHNIQUES IN BROADBAND WIRELESS LANs

This document provides elements for a preliminary draft new Recommendation on characteristics of broadband RLANs under Task 4 of the Joint Rapporteurs Group 8A-9B. The text deals with preferred modulation techniques focusing on orthogonal frequency division multiplexing (OFDM) which has been recognized as a physical layer basis of the IEEE 802.11 standard for a broadband RLAN's modulation scheme operating in the 5GHz band.

1 Introduction

RLAN systems are being marketed all over the world. There are several major standards for broadband wireless LAN systems. ETSI (European Telecommunications Standards Institute) already developed HiperLAN Type-1 standard. Another discussion is currently very active in IEEE 802.11, which established a RLAN standard for the 2.4 GHz band. These standards will stimulate economical RLAN equipment. Broadband wireless LAN systems make it possible to move a computer within a certain area such as an office, a factory, and SOHO (Small Office Home Office) with high data rates of more than 20 Mbit/s. As a consequence of the great progress in this field, computer users are demanding free movement with bit rates equivalent to those of conventional wired LANs such as 10BASE-T Ethernet. This new demand raises significant issues of a stable physical layer for broadband radio transmission. There are two major candidates for this purpose: The one is an equalization scheme and the other is a multi-carrier scheme.

This document presents features of both schemes and comparison between them. Finally a stable high bit rate physical layer which employs DQPSK-OFDM (Orthogonal Frequency Division Multiplexing) with convolutional encoding is recommended.

2 Physical layer to realize high bit rate and stable wireless networks

Broadband radio channel is known to be frequency selective, causing inter symbol interference (ISI) in the time domain and deep notches in the frequency domain. To realize a high speed wireless access system under frequency selective fading channels, a first possible method is to shorten the symbol period, a second way is to use bandwidth efficiently by multi-level modulation, and a third way is to employ multi-carrier modulation. The first and second solutions show serious drawbacks in multipath environments. For the first solution as symbol period is getting shorter, the ISI is getting a severe problem. Therefore, equalization techniques will be necessary. The second solution reduces the symbol distance in the signal space, and hence the margin for thermal noise or interference is decreaced, leading to intolerable performance degradation for high speed wireless access systems. A totally different way to increase the symbol period in order to compensate for ISI coming from multipath propagation, is the third solution: a multi-carrier method. As promising methods for multipath countermeasures the first solution of single carrier with equalizer and the third solution using multi-carrier methods (OFDM) are discussed below.

2.1 Single carrier with Equalizer

In radio communications, the transmission is affected by the time-varying multipath propagation characteristics of the radio channel. To compensate for these time-varying characteristics, it is necessary to use adaptive channel equalization. There are two main groups into which adaptive equalizers can be subdivided; the least mean square (LMS) equalizer and the recursive least squares (RLS) equalizer. The LMS algorithm is the most commonly used equalization algorithm because of its simplicity and stability. Its main disadvantage is its relatively slow convergence. LMS converges in 100-1000 symbols. A faster equalization technique is known as a RLS method. There exist various versions of RLS with somewhat different complexity and convergence trade-off. RLS is more difficult to implement than LMS, but converges in fewer symbols compared with LMS methods. Although many research have been made about RLS and MLS equalizers in the cellular systems, RLS and MLS are still a research topic in the points of fast convergence, stability and complexity for high speed wireless access applications.

2.2 Multi-carrier (Orthogonal Frequency Division multiplex (OFDM))

With multi carrier transmission schemes the nominal frequency band is splitted up into a suitable number of sub-carriers each modulated by QPSK modulation etc. with a low data rate. In general, when dimensioning a multi carrier system, the maximum path delay should be shorter than the symbol time. An OFDM modulation scheme is one of the promising multi carrier methods. The power spectrum of this modulation is shown in Fig. 1. The development of fast and power saving large scale integrated circuits (LSI) and effective algorithms (Fast Fourier Transform: FFT) for signal processing today allows a cost-effective realization of OFDM schemes. The advantages of this system are given by a satisfactory spectral efficiency and in the reduced effort for equalization of the received signal. In the case of limited delay spread(<~300ns) of the multipath signals it is possible to dispense with a equalizer.

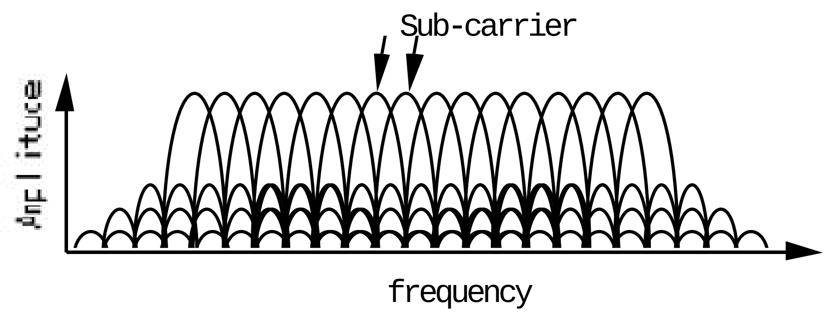

Fig.1 Spectrum of OFDM

2.3 Comparison between OFDM and Equalizer

As discussed in the IEEE 802.11 working group and ETSI BRAN, the OFDM scheme outperforms the equalizer scheme in the following points.

(1) Hardware complexity of OFDM is lower compared with equalizers to combat with a multipath fading channel such as outdoors wireless environment.
(2) Spectral efficiency of OFDM is better compared to GMSK or Offset QPSK with equalizers.
(3) No equalizer training is needed, saving extra complexity and training overhead.
(4) OFDM can support fallback operation with simple hardware.
(5) Larger diversity gain is achieved compared with equalizer.

3 Configuration of OFDM system

A simplified block diagram of the OFDM transmitter and receiver is shown in Fig. 2. The data to be transmitted are coded by convolutional coding (r=3/4, k=7) and serial-parallel converted and the data modulates the allocated sub-carrier by DQPSK modulation. The OFDM signals are generated by the Inverse Fast Fourier Transform (IFFT) of the modulated sub-symbols. Guard Interval (GI) signals are added to the output signals of the IFFT. The GI added OFDM signals are shaped by roll-off amplitude weighting to reduce outband emission. Finally the OFDM signals modulate IF frequency. At the receiver side, received signals are amplified by the Automatic Gain Amp and converted to the baseband signals. At this stage, frequency error due to instability of the RF oscillators is compensated by AFC (Automatic Frequency Control) and the timing of packet arrival is detected. After this synchronization processing, GI signals are removed and the OFDM signals are demultiplexed by the FFT circuit. The output signals of the FFT circuit are fed to the demapping circuit and demodulated. Finally the demodulated signals are decoded by a Viterbi decoder.

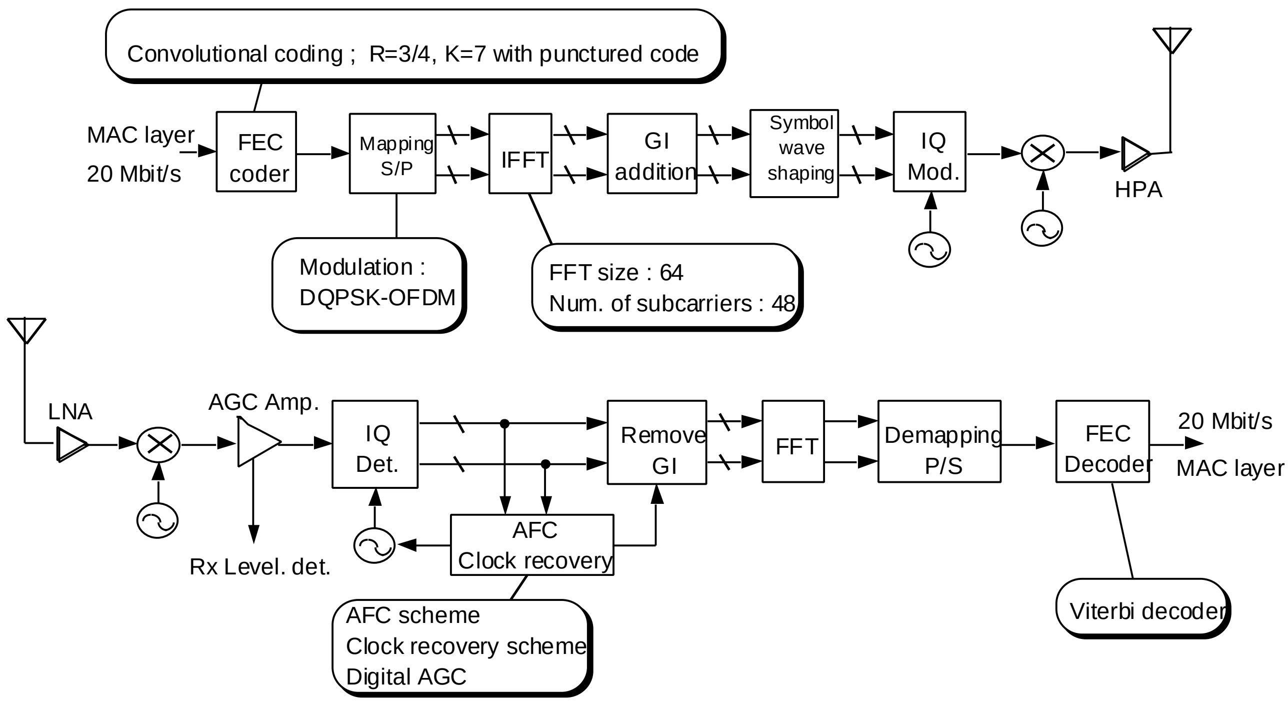

FIG. 2

Configuration of DQPSK-OFDM with convolutional coding

4 Computer simulation

Major simulation parameters and the OFDM symbol format are shown in Table 1 and Fig. 3, respectively. Figure 4 shows that to achieve the packet error rate of 10%, the required Eb/No is about 20dB under the frequency selective fading channel with 300ns delay spread. The proposed physical layer approach allows us to use this high bit rate RLAN system not only in indoor areas but also outdoor areas such as universities, factories, and shopping malls etc..

Table 1 Major simulation parameters.

Raw data rate	26.6 Mbit/s
Modulation / Detection	DQPSK / Differential detection
FFT size	64
Number of sub-carriers	48
Guard interval (GI)	12 samples
Number of Tprefix samples	4 samples
Symbol duration(Ts)	84 samples (=3.6 µs)
Carrier frequency offset	50 kHz (10 ppm at 5 GHz)

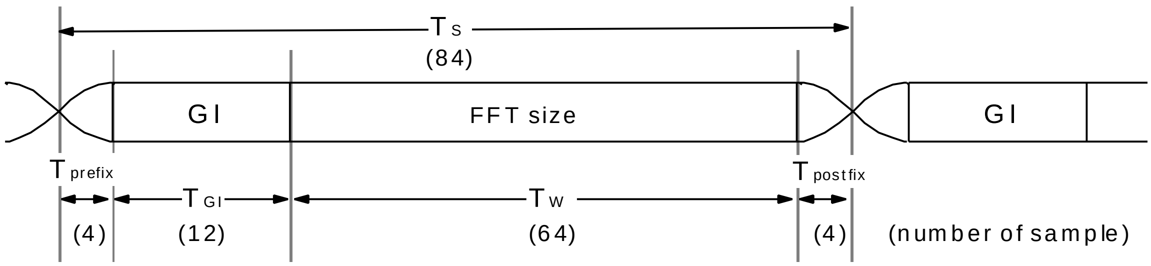

FIG. 3

OFDM symbol format

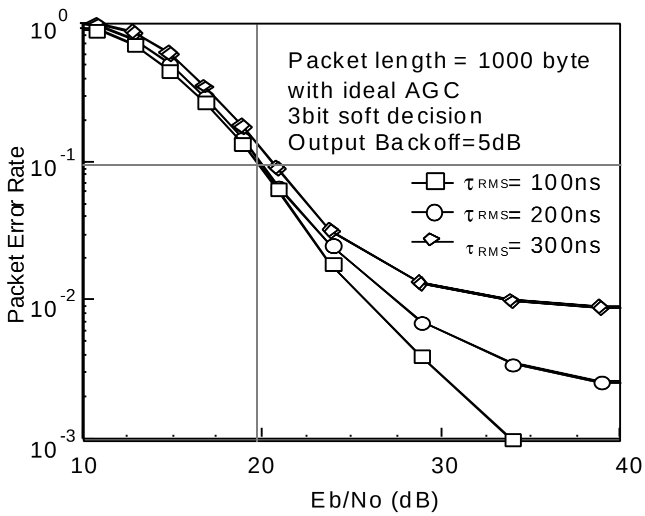

FIG. 4

Packet Error Rate vs Eb/No

5 Conclusion of ANNEX B

This document presented that OFDM is an promising way to realize a high bit rate (more than 20Mbit/s) and stable wireless physical layer. This OFDM scheme has been chosen as a physical layer by IEEE 802.11 standard in July 1998.

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Rapporteur , Task 4