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Title	ADAPTED DVB/DOCSIS PHY PROPOSAL FOR 802.16 BWA SYSTEMS
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Re:	This contribution is submitted in response to the call for contributions from the IEEE 802.16 chair on September 22nd, 1999, for submission of PHY proposals for BWA systems.
Abstract	This document proposes a PHY layer for broadband wireless systems based on satellite and cable communication standards. The recommended downstream PHY layer is based on the ETSI, DVB standard for satellite multimedia broadcasting, [1]. The upstream PHY layer is based on the DOCSIS 1.1 upstream PHY layer, [2]. The proposal presents adapted versions of these standards to better meet the requirements for terrestrial *broadband wireless access* (BWA) networks. The proposed PHY layer allows for the transport of multiple protocols such as IP, ATM, non-compressed digitized voice, audio and video.
Purpose	The purpose of this document is to provide a PHY proposal to the 802.16 PHY task group that will support various types of user traffic, i.e., IP, ATM, trunked data and digitized voice, as well as different types of service, i.e., guaranteed throughput service and maximum error level service.
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ADAPTED DVB/DOCSIS PHY PROPOSAL FOR 802.16 BWA SYSTEMS

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1 Introduction

1.1 *Overview*

This document proposes a PHY layer for broadband wireless systems based on satellite and cable communication standards. The recommended downstream PHY layer is based on the ETSI, DVB standard for satellite multimedia broadcasting, [1]. The upstream PHY layer is based on the DOCSIS 1.1 upstream PHY layer, [2]. The proposal presents adapted versions of these standards to better meet the requirements for terrestrial *broadband wireless access* (BWA) networks. The proposed PHY layer allows for the transport of multiple protocols such as IP, ATM, non-compressed digitized voice, audio and video.

1.2 *Acronyms*

ATM	Asynchronous Transfer Mode
BS	Base Station
BWA	Broadband Wireless Access
DOCSIS	Data-Over-Cable Service Interface Specification
DVB	Digital Video Broadcasting
ETSI	European Telecommunications Standards Institute
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
MAC	Media Access Control
MHz	Megahertz
MPEG	Moving Picture Experts Group
Msym/sec	Megasymbols per second
PDU	Protocol Data Unit
PHY	Physical
PID	Program Identifier
PMD	Physical Medium Dependent
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RS	Reed-Solomon
SI	Service Information
STS	Subscriber Transceiver System
SYNC	Synchronization
TC	Transmission Convergence
TDMA	Time Division Multiple Access
UCD	Upstream Channel Descriptor

1.3 *References*

[1] ETSI, EN 300 421, "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz satellite services", V.1.1.2, August, 1997.
[2] CableLabs, DOCSIS 1.1, "Data-Over-Cable Service Interface Specification, Radio Frequency Interface Specification", Version 1.1, 1999.
[3] ETSI, EN 301 192, "Digital Video Broadcasting (DVB); DVB specification for data broadcasting", V1.2.1, January, 1999.

[4] ISO/IEC 13818-1, "Information technology - Generic coding of moving pictures and associated audio information: Systems", First Edition, April, 1996.

[5] ETSI, EN 300 468, "Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems", V1.3.1, February, 1998.

2 PHY Layer Description

2.1 *Downstream*

The downstream PHY layer consists of a TC (transmission convergence) sublayer and a PMD (physical medium dependent) sublayer. The TC sublayer is based on the TC sublayer described in [2], and the PMD sublayer is based on the PHY described in [1].

2.1.1 TC Sublayer

The downstream is defined as a continuous series of 188-byte MPEG2-TS packets as described in [4]. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload type of the packet and the method of transport being used. The two transport methods being used are data piping and multiprotocol encapsulation. These two transport methods are described in [3]. Each transport stream is identified by the PID value in the MPEG header, [4], in conjunction with the appropriate service information tables, [5]. One protocol is transported per MPEG2 transport stream. The TC sublayer does not allow an adaptation field within MPEG2-TS packets except in the MAC transport stream for carrying the 10.24 MHz network reference clock timing information.

2.1.1.1 Interaction with the MAC layer

2.1.1.1.1 Multiprotocol Encapsulation

In the case of protocols such as IP being transported on the downstream, the TC sublayer uses multiprotocol encapsulation as described in [3] to encapsulate the MAC PDU. The encapsulated PDU is then inserted into the proper transport stream. See section 5.5 of [2] for different insertion scenarios.

2.1.1.1.2 Data Piping

In the case of protocols such as ATM, digitized voice, or MAC management messages, the MAC PDUs are directly inserted into the MPEG2-TS packet payload to be broadcast as described in section 4 of [3].

2.1.1.1.3 Transport Stream Multiplexing

The MAC layer may impose constraints on the TC sublayer with respect to the multiplexing of transport streams. These constraints are to minimize jitter for certain protocols.

2.1.1.2 Interaction with the PMD sublayer

The TC sublayer multiplexes the different transport streams and passes them to the PMD sublayer for transmission. After multiplexing the transport streams, the TC layer ensures that every eighth packets SYNC byte contains the value 0xB8. The SYNC bytes for all other packets shall contain the value 0x47.

2.1.2 PMD Sublayer

The downstream PHY layer is based on the DVB PHY described in [1]. The areas in which the PMD sublayer varies from the DVB PHY are in the supported modulation formats and the baseband shaping.

2.1.2.1 Modulation Schemes

The downstream PHY supports QPSK and 16 QAM, and may support 64 QAM.

2.1.2.2 Baseband Shaping

The baseband filter shall be a root raised cosine filter with α in the range of 0.15 to 0.35.

2.1.2.3 Channel Coding

2.1.2.3.1 Randomisation

The polynomial for the pseudo random binary sequence is $x^{15} + x^{14} + 1$. The randomizer is reinitialized (the seed is reloaded) each time the randomizer encounters a SYNC byte with the value 0xB8. The SYNC bytes are not randomized.

2.1.2.3.2 Outer Coding

The PMD supports the Reed Solomon code RS(204,188,8) which is a shortened version of RS(255,239,8).

2.1.2.3.3 Convolutional Interleaving

The PMD supports convolutional interleaving as illustrated in section 4.4.3 of [1].

2.1.2.3.4 Inner Coding

The PMD shall allow for a range of punctured convolutional codes, based on a rate 1/2 convolutional code with constraint length K=7. The allowed coding rates are 1/2, 2/3, 3/4, 5/6, and 7/8. See table 2 in [1] for punctured code definitions.

2.1.3 Symbol Rate(s) and Bandwidth

The PMD can support symbol rates up to 155 Msym/sec.

2.2 *Upstream*

2.2.1 Overview

The upstream PMD sublayer uses a FDMA/TDMA burst modulation format, which provides seven symbol rates and three modulation formats (QPSK, 16QAM, and 64 QAM where applicable). The PMD sublayer format includes a variable-length modulated burst with precise timing.

The PMD sublayer provides two possible services, guaranteed throughput and maximum error level.

Each burst supports a flexible modulation, preamble, randomization of the payload, and selectable error control encoding.

All of the upstream transmission parameters associated with burst transmission outputs from the STS are configurable by the BS via MAC messaging. Many of the parameters are programmable on a burst-by-burst basis.

The PMD sublayer can support a near-continuous mode of transmission, wherein ramp-down of one burst may overlap the ramp-up of following burst, so that the transmitted envelope is never zero. The system timing of the TDMA transmissions from the various STSs must provide that the center of the last symbol of one burst and the center of the first symbol of the preamble of an immediately following burst are separated by at least the Duration of five symbols. The guard time must be greater than or equal to the duration of five symbols plus the maximum timing error. Both the STS and the BS contribute to the timing error.

2.2.2 Modulation Formats

The modulation formats supported are QPSK, 16 QAM, and 64 QAM where applicable.

2.2.3 Modulation Rates

The upstream modulation rates supported are listed in

Table 1: Modulation Rates

Modulation Format	Modulation Rates Supported
QPSK	1,280, 2,560, 5,120, 10,240, 20,480, 40,960, 81,920 ksym/sec
16 QAM	1,280, 2,560, 5,120, 10,240, 20,480, 40,960 ksym/sec
64 QAM	1,280, 2560, 5,120, 10,240, 20,480 ksym/sec

The symbol rate for each upstream carrier is defined in an Upstream Channel Descriptor (UCD) MAC message.

2.2.4 Spectral Shaping

The upstream PMD sublayer supports 15%-35% Nyquist square root raised cosine shaping.

2.2.5 Upstream Frequency Agility and Range

2.2.6 Spectrum Format

The upstream provides operation with the format $s(t)=I(t)*\cos(\omega t)-Q(t)*\sin(\omega t)$, where t denotes time and ω denotes angular frequency.

2.2.7 Scrambler (Randomizer)

The upstream PMD supports scrambling at either of two locations in the transmit chain, before the RS encoding block and immediately following. The scrambler has a 15-bit seed value that is arbitrarily programmable via the UCD MAC message. The polynomial supported is $x^{15}+x^{14}+1$. The scrambler is illustrated in Figure 2 in [1].

2.2.8 Channel Coding

2.2.8.1 FEC Encoding

The upstream PMD supports RS(64,54,5) encoding. This RS code is a shortened version of the RS(255,245,5) code. The Reed-Solomon generator polynomial supported is:

$$g(x)=(x+\alpha^0)(x+\alpha^1)\ldots(x+\alpha^9)$$, where the primitive element alpha is 0x02.

The Reed-Solomon primitive polynomial supported is:

$$p(x)=x^8+x^4+x^3+x^2+1$$

2.2.8.2 Inner Coding

The upstream PMD supports convolutional encoding at rates 1/2, 2/3, 3/4, 5/6, 7/8, and 1. All coding rates, except for rate=1, are achieved through puncturing the rate 1/2 encoded data stream.

2.2.8.3 Turbo Codes

Turbo codes may be used instead of the concatenated RS and convolutional encoding for a stream of small bursts.

2.2.9 Preamble Prepend

The upstream PMD supports a variable length preamble field that is prepended to the encoded burst. The preamble value is specified through MAC messaging.

2.2.10 Burst Profile

The transmission characteristics are separated into three portions: a) Channel Parameters, b) Burst Profile Attributes, c) STS Unique Parameters. The channel parameters include the symbol rate, the center frequency and the preamble superstring. The burst profile attributes consist of the modulation format, whether differential encoding is being used, the scrambler seed, the maximum burst length (in minislots), the guard time, the scrambling setting, and the error control coding settings. The STS unique parameters consist of the power level, the offset frequency, the ranging offset, the burst length, and the transmit equalizer coefficients.

2.2.11 Service Types

There are two types of services provided by the PMD sublayer: guaranteed throughput, and maximum error level. The first service, has a static encoding rate for the connection regardless of the BER. The traffic using this service should have first priority for the uplink resources. The second service provided by the PMD layer is maximum error level service. This service guarantees a maximum BER by modifying the coding rate through MAC signaling. As the coding rate increases, the MAC layer information throughput for the connection decreases due to the extra parity bits.

2.2.12 Frame Structure

A PMD frame may consist of one or more codewords preceded by a preamble and followed by a guard time then is empty to up to the next minislot. The codewords within a frame are of the same size. The nominal codeword format consists of 54 information bytes followed by 10 parity bytes. The entire codeword may or may be convolutional encoded at any of the coding rates supported. A frame containing non-compressed digitized voice shall bypass the encoding stages of the transmit chain. The actual size of a codeword will depend on the coding rate being used for that burst. In special cases of some small MAC messages, the MAC frame may bypass all PMD coding and the preamble insertion.

3 Benefits

- ✓ The flexibility of the proposed PHY layer coding scheme will allow the seemless integration of voice and data over the same RF channel.
- ✓ The proposed PHY layer allows for guaranteed rate service and maximum error level service.

4 Drawbacks

- ✓ The PHY has a dependence on information from the MAC layer for upstream demodulation.