Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Physical Layer Proposal for BWA**
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Re:	This contribution is submitted in response to the call for contributions for submission of Physical Layer proposals for Broadband Wireless Access (BWA).
Abstract	This Physical Layer proposal is based on the DOCSIS (Data Over Cable Systems Interface Specification) with modifications required for wireless transmission. It is submitted for consideration by the working group for acceptance as the Physical layer standard for BWA.
Purpose	This contribution is submitted as the Physical Layer Standard for BWA
Notice	
Release	

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Physical Layer Proposal for BWA

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Introduction

This contribution proposes that the Physical Layer standard for Broadband Wireless Access be based on the DOCSIS standard with modifications required for Radio Frequency transmission. The development of modems for BWA using DOCSIS based standards should be possible at lower cost and shorter cycle times since the component parts (both hardware and software) have been developed for cable modems and can be modified for the unique requirements of BWA. Unique to BWA, is the need to define a flexible air interface frequency plan that supports both FDD and TDD systems. This contribution proposes such a frequency plan as part of this PHY standard.

The remainder of this submission will use the paragraph numbering of IEEE 802.16-99/06D0, Outline of the 802.16.1 Air Interface Standard to allow ease of reference. Complete of some paragraphs of the outline are deferred to a later date due to the need for co-development with other participants and the time constraints of submittal for session #4 consideration.

4 Physical Layer

4.1 Scope

The electrical and protocol characteristics of the Physical Layer (PHY) for Broadband Wireless Access are define in this section of the 802.16.1 Air Interface Standard.

4.2 Normative References

Deferred to a later date.

4.3 Physical Layer Overview

4.3.1 Introduction

The Physical Layer is comprised of two sublayers called the Transmission Convergence sublayer and the Physical Media Dependent sublayer. The Transmission Convergence sublayer is present in the downstream direction only.

4.3.2 Reference Configuration

The transmission path for BWA is realized at the headend by the Base Station (BST) and at each customer by the Customer Premises Equipment (CPE). The BST consists of broadcast transmitters and receivers arranged to cover a sector of a cell. The BST modems provide the interface between the RF equipment and the Wide-Area Network. The CPE consist of a highly directional transceiver and the customer modem.

4.3.3 Multiple Access

4.3.3.1 Duplexing

BWA systems may use either FDD or TDD or both. In all cases the primary mode of operation will be FDM/TDMA for the upstream path and FDM/TDM for the downstream.

4.3.3.2 Frames, Multiframes & Hyperframes

The MPEG-2 packet stream shall be encoded according to [ITU-T J.83-B], including MPEG-2 transport framing using a parity checksum as described in [ITU-T J.83-B].

In the upstream direction, the PHY layer indicates the start of the MAC frame to the MAC sublayer. From the MAC sublayer's perspective, it only needs to know the total amount of overhead so it can account for it in the
Bandwidth Allocation process. The FEC overhead is spread throughout the MAC frame and is assumed to be transparent to the MAC data
stream. The MAC sublayer does need to be able to account for the overhead when doing Bandwidth Allocation.

4.3.3.3 Time Slots & Bursts

The upstream channel is characterized by many transmitters (CPEs) and one receiver (the BST). Time in the upstream channel is slotted, providing for Time Division Multiple Access at regulated time ticks. The BST provides the time reference and controls the allowed usage for each interval. Intervals may be granted for transmissions by particular CPEs, or for contention by all CPEs. CPEs may contend to request transmission time. To a limited extent, CPEs may also contend to transmit actual data. In both cases, collisions can occur and retries are used.

4.3.3.4 Logical Channels

Deferred to a later time.

4.3.4 Coding, Interleaving & Scrambling

Deferred to a later time.

4.3.5 Modulation

The PHY must provide upstream and downstream modulation formats of QPSK, 8-QAM/PSK, 16-QAM and 64-QAM.

4.3.6 RF Transmission & Reception

The combination of BST and CPE electrical characteristics must support transmission of the specified modulation types and rate over a range of 200 meters to 5000 meters. The system must have sufficient margin to maintain a bit error rate, without FEC, lower than $1x10^{-4}$ at 99.9% reliability for the rain region in which the system is deployed.

4.3.7 Band Plan & Channelization

The frequency range of operation will be within 10 to 40 GHz. The bandplan and channelization will be modeled after that defined in paragraph 4.7.1.1. No specific channel bandwidth is defined. Rather the bandwidth can be selected for both the upstream and downstream directions to meet various traffic requirements. However, the channel spacing should be based on an integer multiple of 1.25 MHz.

4.3.8 Other PHY related functions

Deferred to a later time.

4.4 Multiple Access & Channel Multiplexing

4.4.1 Introduction

Deferred to a later time

4.4.2 Physical Resource

4.4.2.1 RF Channel

RF channel frequency and bandwidth will be determined by the BST based on the service request from the MAC. The BST will command the CPE modem to the appropriate frequencies, modulation type and modulation rate for reception and transmission on a channel pair for two-way data, telephony or video.

4.4.2.2 Framing & Formatting

Deferred to a later time

4.4.3 Logical Channels

Deferred to a later time

4.4.3.1 Hierarchy

Deferred to a later time

4.4.3.2 Traffic Channels (TCHs)

Deferred to a later time

4.4.3.3 Control Channels (CCHs)

Deferred to a later time

4.4.4 Types of Physical Channels

The Physical (PHY) layer is comprised of two sublayers:

• Transmission Convergence sublayer (present in the downstream direction only)

• Physical Media Dependent (PMD) sublayer.

4.4.4.1 Downstream Transmission Convergence Sublayer

The Downstream Transmission Convergence sublayer exists in the downstream direction only. It provides an opportunity for additional services over the physical-layer bitstream. These additional services might include, for example, digital video. Definition of any such additional services is beyond the scope of this document.

This sublayer is defined as a continuous series of 188-byte MPEG [ITU-T H.222.0] packets, each consisting of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the MAC. Other values of the header may indicate other payloads. The mixture of payloads is arbitrary and controlled by the BST.

The Downstream Transmission Convergence sublayer is defined in Section 4.4.5.2 of this document.

4.4.4.2 Physical Media Dependent Sublayer

The PMD sublayer involves digitally modulated RF carriers on the analog cable network. In the downstream direction, the PMD sublayer is based on [ITU J.83-B], with certain exceptions and includes these features:

• QPSK, 8-QAM/PSK, 16-QAM and 64-QAM modulation formats

• Concatenation of Reed-Solomon block code and Trellis code supports operation in a higher percentage of networks

• Variable-depth interleaver supports both latency-sensitive and -insensitive data.

The features in the upstream direction are as follows:

• Flexible and programmable CPE under control of the BST

• Frequency agility

• Time division multiple access

• QPSK, 8-QAM/PSK, 16-QAM and 64-QAM modulation formats

• Support of both fixed-frame and variable-length PDU formats

• Multiple symbol rates

• Programmable Reed-Solomon block coding

• Programmable preambles

The PMD is defined in section 4.4.5.1 of this specification.

4.4.5 Mapping of Logical Channels into Physical Channels

4.4.5.1 Physical Layer Specification

4.4.5.1.1 Upstream

4.4.5.1.1.1 Overview

The upstream Physical Media Dependent (PMD) sublayer uses a FDMA/TDMA burst modulation format. The modulation format includes pulse shaping for spectral efficiency, is carrier-frequency agile, and has selectable output power level. The PMD sublayer format includes a variable-length modulated burst with precise timing beginning at boundaries spaced at integer multiples of TBD **m**sec apart (which is 16 symbols at the highest data rate).

Each burst supports a flexible modulation, symbol rate, preamble, randomization of the payload, and programmable FEC encoding.

All of the upstream transmission parameters associated with burst transmission outputs from the CPE are configurable by the BST 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 the following burst, so that the transmitted envelope is never zero. The system timing of the TDMA transmissions from the various CPEs shall 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 shall be greater than or equal to the duration of five symbols plus the maximum timing error. Timing error is contributed by both the CPE and BST. CPE timing performance is specified in Section TBD. Maximum timing error and guard time may vary with BSTs from different vendors.

The upstream modulator is part of the CPE modem which interfaces with the network. The modulator contains the actual electrical-level modulation function and the digital signal-processing function; the latter provides the FEC, preamble prepend, symbol mapping, and other processing steps. This specification is written with the idea of buffering the bursts in the signal processing portion, and with the signal processing portion (1) accepting the information stream a burst at a time, (2) processing this stream into a complete burst of symbols for the modulator, and (3) feeding the properly-timed bursted symbol stream to a memoryless modulator at the exact burst transmit time. The memoryless portion of the modulator only performs pulse shaping and quadrature upconversion.

At the Demodulator, similar to the Modulator, there are two basic functional components: the demodulation function and the signal processing function. Unlike the Modulator, the Demodulator resides in the BST and the specification is written with the concept that there will be one demodulation function (not necessarily an actual physical demodulator) for each carrier frequency in use. The demodulation function would receive all bursts on a given frequency.

Note: The unit design approach should be cognizant of the multiple-channel nature of the demodulation and signal processing to be carried out at the headend, and partition/share functionality appropriately to optimally leverage the multi-channel application. A Demodulator design supporting multiple channels in a Demodulator unit may be appropriate.

The demodulation function of the Demodulator accepts a varying-level signal centered around a commanded power level and performs symbol timing and carrier recovery and tracking, burst acquisition, and demodulation. Additionally, the demodulation function provides an estimate of burst timing relative to a reference edge, an estimate of received signal power, an estimate of signal-to-noise ratio, and may engage adaptive equalization to mitigate the effects of a) echoes, b) narrowband ingress and c) group delay. The signal-processing function of the Demodulator performs the inverse processing of the signal-processing function of the Modulator. This includes accepting the demodulated burst data stream and decoding, etc., and possibly multiplexing the data from multiple channels into a single output stream. The signal-processing function also provides the edge-timing reference and gating-enable signal to the demodulators to activate the burst acquisition for each assigned burst slot. The signal-processing function may also provide an indication of successful decoding, decoding error, or fail-to-decode for each codeword and the number of corrected Reed-Solomon symbols in each codeword. For every upstream burst, the BST has a prior knowledge of the exact burst length in symbols.

4.4.5.1.2 Downstream

4.4.5.1.2.1 Downstream Protocol

The downstream PMD sublayer shall conform to ITU-T Recommendations J.83, Annex B for Low-Delay Video Applications [ITU J.83-B], with exceptions.

The downstream PMD sublayer shall support a variable-depth interleaver with the characteristics defined found in [ITU J.83-B]. The interleaver depth, which is coded in a 4-bit control word contained in the FEC frame synchronization trailer, always reflects the interleaving in the immediately-following frame. In addition, errors are allowed while the interleaver memory is flushed after a change in interleaving is indicated.
Refer to [ITU J.83-B] for the control bit specifications required to specify which interleaving mode is used.

4.4.5.2 Downstream Transmission Convergence Sublayer

4.4.5.2.1 Introduction

In order to improve demodulation robustness, facilitate common receiving hardware for both video and data, and provide an opportunity for the possible future multiplexing of video and data over the PMD sublayer bitstream, a sublayer is interposed between the downstream PMD sublayer and the MAC sublayer.

The downstream bitstream is defined as a continuous series of 188-byte MPEG [ITU-T H.222.0] packets. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the MAC. Other values of the header may indicate other payloads. The mixture of MAC payloads and those of other services is optional and is controlled by the BST.

4.4.6 PHY-MAC Interaction

Deferred to a later time

4.4.6.1 Downstream

Deferred to a later time

4.4.6.2 Upstream

Deferred to a later time

4.5 Channel Coding

4.5.3 Introduction

Deferred to a later time

4.5.4 Downstream Coding Scheme

Deferred to a later time

4.5.5 Upstream Coding Scheme

Deferred to a later time

4.6 Modulation

4.6.3 Introduction

The BWA system must provide upstream and downstream modulation formats of QPSK, 8-QAM/PSK, 16-QAM and 64-QAM. The modulation type and rate will be set by the BST through the Convergence Layer.

The BST may switch modulation types and rates to overcome environmental conditions such as rain to maintain BER performance.

4.6.2 Downstream Modulation

4.6.2.1 Modulation Type(s)

The BWA system must provide downstream modulation formats of QPSK, 8-QAM/PSK, 16-QAM and 64-QAM.

4.6.2.2 Modulation Rate(s)

The BWA must provide variable and selectable modulation rates from 1.544 Mbps to 51.84 Mbps (user data rate) in steps consistent with MPEG structure.

4.6.2.3 Modulation Symbol Definition & Mapping

Symbol definition and mapping shall be per the DOSIS definition and standards cited.

4.6.3 Upstream Modulation

4.6.3.1 Modulation Type(s)

The BWA system must provide downstream modulation formats of QPSK, 8-QAM/PSK, 16-QAM and 64-QAM

4.6.3.2 Modulation Rate(s)

The BWA must provide variable and selectable modulation rates from 1.544Msym/s to 51.84 Msym/s (user data rate) in steps consistent with MPEG structure.

4.6.3.3 Modulation Symbol Definition & Mapping

Symbol definition and mapping shall be per the DOSIS definition and standards cited.

4.7 RF Transmission & Reception

4.7.1 Frequency Bands & Channel Arrangement

The following channel arrangement and constraints will permit interoperability of TDD and FDD system flexibility.

- Channel centering to within 1.25 MHz integer increments measured from band edge. This limits channel bandwidths to integer multiples of 1.25 MHz but does not specify bandwidths. It is left to the system designer to choose bandwidths suitable for that system subject to the above conditions.

- Frequency accuracy: 1 ppm maximum

- No downstream transmitters will radiate -30 dBm power above 27.925 GHz and no upstream transmitters will radiate -30 dBm power below 27.925 GHz.

- The FDD BST output power into the antenna shall be less than or equal to -40 dBm above 27.925 GHz

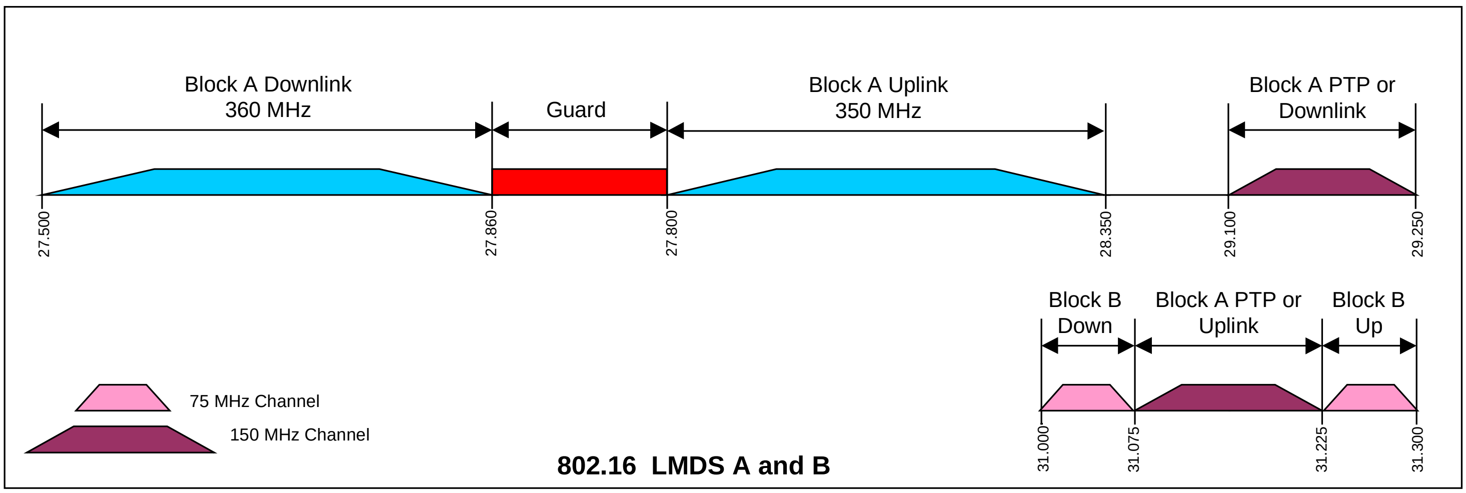
- The FDD CPE output power into the antenna shall be less than or equal to -70 dBm below 27.925 GHz

- No FDD system BST will transmit on frequencies greater than 27.925 GHz

- No FDD system CPE will transmit on frequencies below 27.925 Ghz

- Block B downstream is 31.0 to 31.075 GHz and upstream is 31.225 to 31.3 GHz for BST to CPE systems

4.7.1.1 LMDS Block A and B



The LMDS block A and B frequency plan is shown in the figure above.

4.7.1.2 Others

BWA systems operating at other frequencies from 10 GHz to 40 GHz will conform to regulatory channel and frequency plans or use plans based on the LMDS plan. Details to be provided later

4.8 Radio Sub-system Control & Synchronization

4.8.1 Introduction

4.8.2 Timing & Synchronization

4.8.2.1 Base Station

The BST shall control the timing and synchronization of the cell by providing timing and synchronization commands to the CPE.

4.8.2.2 CPE

The CPE shall accept timing and synchronization commands from the BST and the modem shall adjust its transmission to occur within its assigned time slot during TDMA operation. The CPE shall have the ability to synchronize both carrier frequency and clock frequency to the frequency of signals received from the base station.

4.8.3 Power Control

The BST shall adjust its output power to maintain the quality of service at all CPE sites within the sector. The BST shall command the CPE transmit power to a level that causes all CPE signals within the sector to arrive at the BST within ±2 dB of the nominal operating signal level.

4.8.4 Radio Link Measurements

4.8.4.1 RSSI

Deferred to a later date

4.8.4.2 Signal Quality

Both the BST and CPE modems shall have provisions for determining signal quality. The CPE shall report its signal quality to the BST.

4.8.5 Additional PHY related Registration Functions

4.8.5.1 Ranging

Ranging is the process of acquiring the correct timing offset such that the CPE's transmissions are aligned to the correct mini-slot boundary. The timing delays through the PHY layer shall be relatively constant. Any variation in the PHY delays shall be accounted for in the guard time of the upstream PMD overhead.

First, a CPE shall synchronize to the downstream and learn the upstream channel characteristics through the Upstream Channel Descriptor MAC management message. At this point, the CPE shall scan the Bandwidth Allocation MAP message to find an Initial Maintenance Region. Refer to Section 6.4.1.1.4 of DOCSIS

4.8.5.2 Power Leveling

The power level of the CPE transmitter must be adjusted such that all upstream signals arriving at the BST in a sector are within ±2 dB of the nominal operating point of the BST. The BST modem shall use its QOS function to derive the information require to adjust the CPE modems output power and hence the CPE's transmitter power to the correct level.

4.8.6 PHY-MAC Service Access Points

Deferred to a later time

4.8.6.1 Primitives

Deferred to a later time

4.8.6.2 Messages

Deferred to a later time

4.9 Minimum Performance

4.9.1 Reference Test Plans

4.9.2 Propagation Models

4.9.3 Transmitter Characteristics

4.9.3.1 FDD

4.9.3.1.1 Downstream

4.9.3.1.2 Upstream

4.9.3.2 TDD

4.9.3.2.1 Downstream

4.9.3.2.2 Upstream

4.9.4 Receiver Characteristics

4.9.4.1 FDD

4.9.4.1.1 Downstream

4.9.4.1.2 Upstream

4.9.4.2 TDD

4.9.4.2.1 Downstream

4.9.4.2.2 Upstream

4.9.5 Transmitter & Receiver Performance

4.9.5.1 Modulation Accuracy

4.9.5.2 …