

Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >	
Title	Initial PHY Proposal for 802.16.3	
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Re:	This proposed PHY is in response to the Call for Contributions: Session #10, of the IEEE 802.16.3 Task Group, upon the topic "Initial PHY Proposals," document IEEE802.16.3-00/14, dated 2000-09-15.	
Abstract	This proposed PHY addresses the criteria in the Evaluation Table of the cited Call for Contributions with a flexibly scalable structure based on existing wireless standards, which can efficiently respond to the 802.16.3 Functional Requirements Document and support cost-effective implementations over alternative PHY structures.	
Purpose	This document is proposed for consideration by the 802.16.3 Task Group as the 2-11 GHz Licensed Band FWA PHY solution.	
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802.16.3 PHY: Initial Proposal

System Overview

The proposed PHYSical model is based upon using bi-directional orthogonal frequency-division-multiplexing (OFDM), with scalable symbol rates to accommodate available bandwidth. This PHY layer approach is based directly on the PHY layer used by both ETSI HIPERLAN2 and the IEEE 802.11a standards. To accommodate the more demanding challenge posed by greater link distances and distortions, optional features are also proposed (e.g. transmit-diversity, and iterative decoding). The proposed optional extensions to these existing PHY standards are themselves already part of existing standards. The iterative decoding option is identical to that proposed as an optional part of the IEEE 802.16.1 draft standard, and the transmit-diversity scheme is identical to that already adopted as part of the 3G open standards (WCDMA 3GPP FDD mode, WCDMA 3GPP TDD mode, CDMA2000 and EDGE.)

The proposed PHY is MAC-agnostic, facilitating transition between currently available and rapidly emerging MACs which have been optimized for broadband fixed wireless applications. While the PHY shown in figure 1 addresses FDD applications, the OFDM modem required for such applications would be readily adaptable to support SFDD or TDD schemes as well.

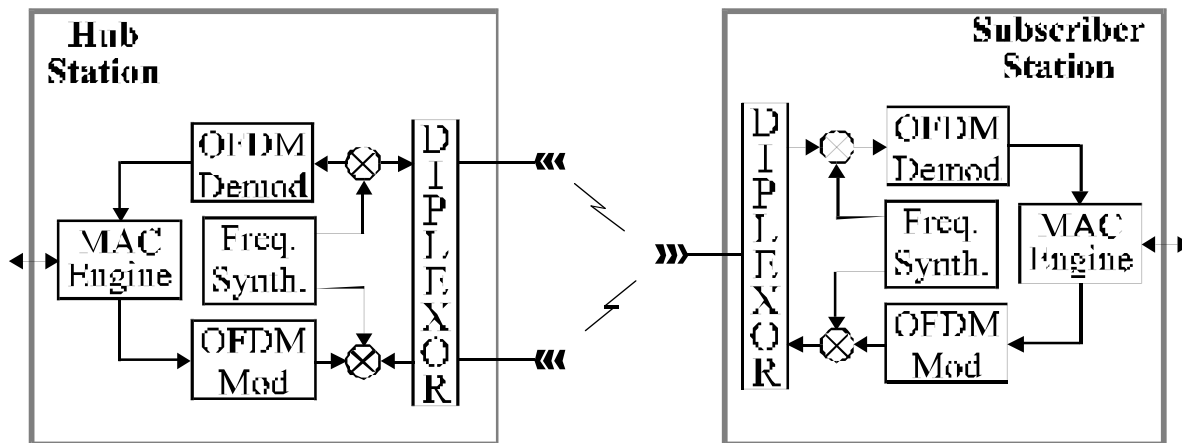


Figure 1. PHY Layer System Reference Model

Proposed PHY Layer

The primary features of the proposed PHY are summarized below:

Forward Link:

- Modulation: OFDM, based on 64FFT, with cyclic prefix, per HIPERLAN2
- FEC: K=7 trellis code with tail-biting, puncturing, per HIPERLAN2
- $R_s \leq 40$ Mbaud; $R_b: \leq 40 - 155$ Mbps
- Scrambling + intra-frame interleaving
- BPSK, QPSK, 16QAM and 64QAM
- Burst: supports TDD, FDD, FDMA, TDMA
- *Optional*: 2-way transmit-diversity

Return Link:

- Modulation: OFDM, based on 64FFT, with cyclic prefix, per HIPERLAN2
- FEC: K=7 trellis code with tail-biting, puncturing, per HIPERLAN2
- $R_s \leq 20$ Mbaud; $R_b \leq 54$ Mbps
- Scrambling + intra-frame interleaving
- BPSK, QPSK, 16QAM and 64QAM
- Burst: supports TDD, FDD, FDMA, TDMA
- *Optional*: Iterative decoding, per 802.16.1

Reference Model

The proposed PHY layer supports all required functions described in the 802.16.3 Functional Requirements

Document (FRD). The interfaces between the proposed PHY and other layers and sub-layers of the ISO stack are depicted in figure 2.

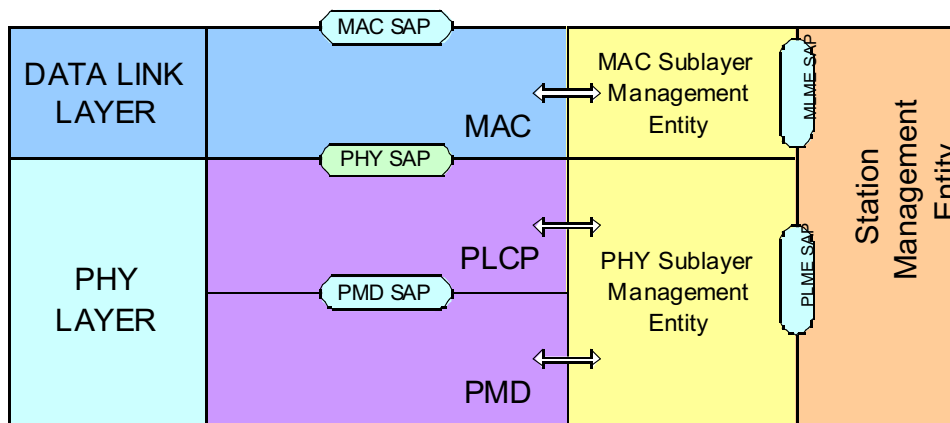


Figure 2. Reference Model of PHY and Interfaces to other ISO Layers

Proposed PHY Benefits

The primary benefits of the proposed PHY approach are readily summarized:

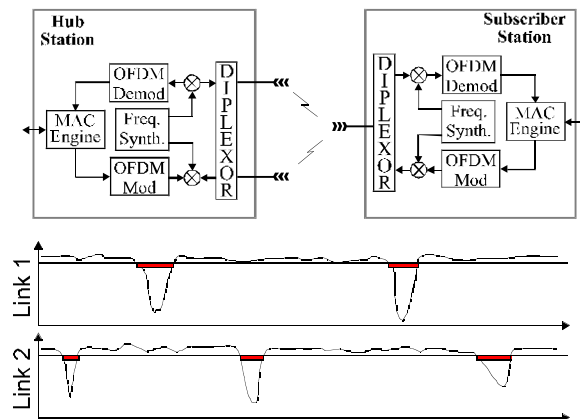
OFDM is the most highly robust modulation technique available, with its implicit channelization rendering all channels effectively non-dispersive. This in turn makes OFDM highly robust to even severe propagation channel distortion, even over links characterized by very low K-factors (Ricean links), even K=0 (Rayleigh links).

Moreover, OFDM offers a very flexible means, symbol erasures, of adapting to channel dynamics in a simple and robust manner.

This PHY is directly based on existing standards, thus offering rapid time-to-market. Service providers cannot afford to wait for PHY solutions which will not be available for years. However, numerous IC vendors already have modem solutions nearing completion to support the 802.11a and ETSI HIPERLAN standards. These modem ICs may be readily adapted to serve the 802.16.3 marketplace, satisfying the time-to-market constraints, while piggybacking on the already large demand for modem ICs satisfying those large and growing markets.

The proposed optional modifications to these standard PHY solutions address the challenges posed by the added distortion associated with 802.16.3 links, and with the much larger propagation loss. Optional iterative decoding on return link enhances capacity while reducing the peak power levels required of the subscriber high-power amplifiers. The encoders associated with this feature add negligible complexity to the cost-sensitive subscriber equipment; the added complexity of the decoding is borne by the less cost-sensitive hub equipment. Similarly, optional use of transmit-diversity requires negligible increase in subscriber equipment complexity, yet offers very large improvements in service over links exhibiting Rayleigh fading. In markets and applications which exhibit low K-values, use of this optional feature can dramatically improve link availability.

More specifically, using Alamouti's technique [1], it is relatively simple to obtain full two-fold diversity using a single subscriber antenna and two hub antennas. Simply put, links over Rayleigh fading channels will always exhibit signal drop-out, with the frequency of this outage event tied to the channel statistics and the signal bandwidth. Two-way diversity means that the link remains reliable so long as either of the independent links remains viable; figure 3 depicts this situation. In other words, two-way diversity means that, instead of a link offering 99% availability, the same link would support 99.99% availability. That such a significant link availability improvement is achievable with negligible incremental complexity is remarkable, and is a strong argument for including transmit-diversity in the 802.16.3 PHY standard.



Drawbacks of Proposed PHY

The primary drawback of the proposed PHY architecture is that it is not interoperable with PHY architectures based on cable-modem technology. This PHY is optimized specifically for fixed broadband wireless access, with features tailored precisely to the unique character of the costs and complexities of the propagation channels associated with those links. As such, it represents a need to evolve beyond the simple cable modem technologies already brought to this market. However, while this represents a discontinuity, it also offers the opportunity for the dramatic cost reductions and link reliability improvements required to make fixed BWA a commercial success.

Relation to Existing Standards

The proposed PHY standard has very little in common with the two standards based on the cable-modem PHY technology, specifically, ITU-R JRG 8A-9B and DOCSIS 1.1. However, the proposed PHY solution is very nearly identical to the two open standards for wireless LANs, the IEEE 802.11a and ETSI HIPERLAN2. The only differences between the proposed PHY and these standard wireless PHY solutions is motivated by the differences between the link distances and channel distortion for the 802.16.3 channel and the LAN channels. Specifically, we propose to address the greater propagation loss of the 802.16.3 channel by introducing an optional iterative decoding, with the specific iterative coding approach identical to that adopted as an option to the 802.16.1 PHY standard. In addition, reflecting the far greater distortion of the 802.16.3 channels, we propose an additional option, transmit-diversity, to address the phenomenon of channel outage in a very economical way.

Scalability per 802.16.3 Functional Requirements Document (Rev 4)

The proposed PHY standard will support all aspects of the 802.16.3 FRD, and this PHY proposal can be scaled to accommodate virtually any channel bandwidth assignment or spacing.

Intellectual Property Rights

As noted on the cover page, this PHY proposal is made subject to the IEEE rules regarding intellectual property. In addition, the optional iterative decoding technique has already been submitted to the 802.16.1 standard as an optional part of that standard's PHY layer, where IEEE IPR conditions have been met. Finally, the transmit-diversity scheme proposed as an option has already been adopted by all 3G mobile wireless standards, including: WCDMA, 3GPP FDD mode, WCDMA 3GPP TDD mode, CDMA2000 and EDGE; the receiver processing for this transmit-diversity scheme is mandatory for all cited 3G mobile standards.

References

- 1) S. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," *IEEE J. Select. Areas Commun.*, vol. 16, pp. 1451-1458, October 1998.
- 2) P80211aD7.0. – Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: High Speed Physical Layer in the 5 GHz Band.
- 3) ETSI Broadband Radio Access Networks (BRAN); HIPERLAN Type 2 Technical Specification; Physical (PHY) Layer.