Project	**IEEE 802.16.3 Broadband Wireless Access Working Group <http://ieee802.org/16>**	
Title	**Initial PHY proposal for the IEEE802.16.3 Air Interface Standard**	
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Re:	IEEE802.16.3-00/14 Call for Contributions on the topic: Initial PHY Proposals	
Abstract	We give an initial PHY layer proposal for the IEEE 802.16.3 BWA air interface standard for the licensed bands from 2 to 11 GHz.	
Purpose	This contribution will be presented and discussed within Session #10 for a vote as a possible PHY layer for the IEEE802.16.3 Air Interface Standard	
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Initial PHY Proposal For IEEE802.16.3 Air Interface 2

Initial PHY Proposal For IEEE802.16.3 Air Interface

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1.0 PHY Overview

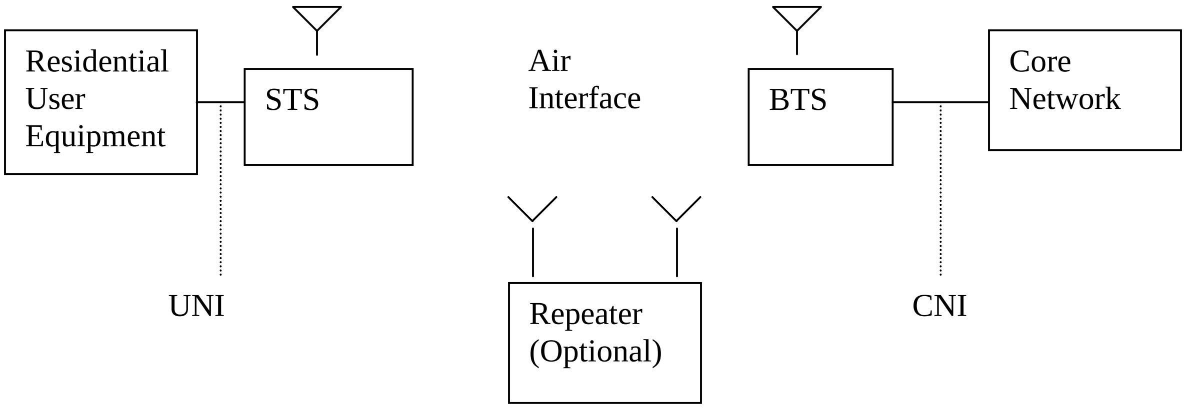
1.1 Introduction

This proposal addresses the issue of a PHY protocol for the IEEE802.16.3 Broadband Wireless Access (BWA) air interface standard. Some concepts and mechanisms are taken from existing industry standards [2] – [10] to allow rapid development and cost optimization. In particular, this proposal borrows concepts from Annex B of ITU-T Recommendation J.112 “Data over Cable Radio Frequency Interface” [2] and the ITU-R 8A-9B draft for Fixed BWA [2a], which underlines the continuous mode of operation in the draft STD of IEEE802.16.1. [10]. Some other concepts are adapted from IEEE802.16.1 MODE B among them is the adaptive modulation and Block Turbo Coding.

In order to comply with the IEEE802.16.3 system requirements (see Reference [1]) several necessary improvements are recommended. These recommendations include:

- Adaptive modulation & coding (AMC) capability must be supported for both the upstream and downstream transmissions.
- More powerful and flexible coding scheme enabling iterative Soft-in\Soft-out turbo decoding [11] are suggested. In particular, Block Turbo Coding (BTC) scheme [12] optimized to support variable-length IP datagrams combined with higher-level modulations and high code rate is proposed.
- Advanced single carrier based on M-QAM with a non-linear decision feedback equalizer mechanism at the receiver to enhance the performance in a selective fading scenario.
- A migration approach based on joint equalization and turbo decoding (“Turbo Equalizer”) and diversity receiver for providing improved performance with seamless changes in the receiver structure.

1.2 Reference Configuration



The Air Interfaces defined in this proposal are:

- Between the Base Transceiver Station (BTS) radio and the Subscriber Transceiver Station (STS) radio in the downstream direction.
- Between the BTS radio and the STS radio in the upstream direction.
- An optional repeater between STS and BTS deployment is supported

The Core Network Interfaces (CNI) and User Network Interface (UNI) are beyond the scope of this document.

RF interface points are defined as:

- In/Out at the STS Modem
- In/Out at the BTS Modem
- (Optional) In/Out at the repeater

1.3 Communications protocols

The PHY layer is comprised of two sub-layers:

- Physical Media Dependent (PMD) sub-layer. The PMD sub-layer involves the main processing parts of the PHY layer including: filtering and equalization, synchronization, randomizing, FEC encoding\decoding and interleaving, baseband pulse shaping and other baseband processing units to enhance digitally modulated RF carriers over- the-air.
- Transmission Convergence (TC) sub-layer. This sub-layer is defined to adapt and map certain MAC services (such as changing resource allocations) to generic PMD services.

These parts will be addressed briefly in the sequel and in more details at later stages of the standard development process.

1.4 Main features and benefits

This PHY proposal for the IEEE802.16.3 air interface standard presents basic features that meet all the requirements identified in [1], under the critical constraint of low-cost solution to the target markets. A migration approach that will enable an exploitation of current industry standards and systems is indicated. Further advanced features are recommended to improve the performance in a number of ways. Benefits of the proposed PHY and its unique features are outlined below:

- **Matured and well approved technology** - build on the footprint of the evolving cable modem technology and borrowing key features from well-established wireless standards ([2] - [10]).
- **Adaptive Modulation and Coding (AMC) -** allowing flexible bandwidth allocation to maximize spectral efficiency and overall system capacity. For example, near STS can use higher modulation scheme with high coding rate, while far STS or other STS experiencing severe interference profile can use more robust QPSK modulation. AMC exhibits more than 20dB gain relative to non-adaptive schemes.

- **Flexible Asymmetry –** supporting high degree of flexibility between delivered upstream and downstream via several duplexing schemes – FDD, TDD and FSDD.
- **Scalability -** supporting IP, ATM and MPEG-2 packets with variable-length Packet Data Units (PDU).
- **High immunity to RF impairments and radio equipment impairment**– the proposal is based on single carrier M-QAM that is less sensitive than OFDM to RF impairments such as: linearity of power amplifier, frequency instability, phase noise, synchronization errors, Doppler spread etc
- **Advanced Coding Schemes –** based on Block Turbo Coding (BTC) outperforms convolutional coding schemes and Reed-Solomon concatenated with convolutional codes. BTC provides the best solution for variable packet length with high code rate.
- **Reduced System Delay** - due to advanced Block Turbo Coding that eliminates the need for a large interleaver required with the concatenated coding schemes.
- **Reduction in cost, complexity and network architecture simplification.** Advanced single carrier modulation based on M-QAM combined with adequate equalizing techniques and BTC reduces the overall system complexity.
- **Migration approach** from basic to more advanced systems that meet more demanding channel impairments and interference at increased spectrum efficiency. Migration to joint equalization and Turbo decoding (i.e., Turbo-Equalization, TE) will enable seamless transition to improved performance receivers. A migration to diversity receiver and multiple-input/multiple-output (MIMO) will improve the robustness to interference, channel impairments and radio equipment impairment at a cost of increased complexity.

2.0 Multiple Access Technology

Downstream uses Time Division Multiplexing (TDM). In TDM operation the downstream is based upon time division multiplexing, where the information for each STS is multiplexed onto the same stream of data, and is received by all STS located within the same sector. In the suggested TDM operation mode the downlink is composed of a Frame. Each Frame starts with a Preamble followed by the transmitted data. In order to support Adaptive Modulation the lower modulation schemes are initially transmitted followed by the higher modulation schemes.

Upstream uses TDMA and Demand Assigned Multiple Access (DAMA). The MAC layer controls the number of time slots assigned in the upstream for various uses.

3.0 Duplex Schemes

Several duplexing schemes are supported by this PHY layer proposal.

Mandatory

FDD (Frequency Division Duplexing)**:** In this mode upstream and downstream transmission channels are located on separate frequencies, where frequency separation is determined by Transmitter/Receiver performance requirements or regulatory requirements.

Optional
TDD: In this case, the upstream and the downstream transmissions share the same frequency, but are separated in time. A gap in time is required to switch from transmit mode to receive mode.

FSDD: This mode refers to a system in which some of the STS cannot transmit and receive at same time. i.e., this group of users has half-duplex capability. In this mode downstream and upstream transmission channels are be located at separate frequencies.

4.0 RF Propagation Characteristics and Diversity Techniques

The channel model is highly dependent upon the RF network topology, RF bands, terrain category and the various RF propagation impairments (see [13]-[18]).

4.1) RF Network topology
<u>Mega-cell topology</u>: up to 50 km Tx\Rx separation, LOS propagation. Directive antenna at both BTS and CPE, negligible Co-Channel-Interference (CCI).

<u>Multi-cell topology</u>: cell radius typically less then 10 km. Frequency re-use cellular system. A cell may be subdivided into sectors.

<u>4.2) Single-Input/Single-Output (SISO) Vs. Multiple-Input/Multiple-Output (MIMO):</u>
Multiple antennas can be used at the transmitter and/or receiver to provide added dimension to the model. When compared to SISO, MIMO techniques can improve the capacity of the fading wireless channel regardless of the modulation techniques utilized. It is applicable to single carrier (SC) modulation (see [15] and IEEE802.16.3p-00/11). The benefits, however, of using space diversity should be examined against its implementation complexity (cost) and economic factors.

4.3) RF bands and Channelization:
Frequency range 2 to 11 GHz
Channelization: support 1.75, 3.5 and 7 MHZ using ETSI frequency masks (3.5GHz systems) and 1.5, 3, and 6 using MDS mask (2.5 Mhz systems).
Supporting 0.5 to 7 MHz when using other masks and frequency plans.

The details will be provided within an Appendix (Regulatory requirements)

4.4) Terrain category:

- Urban
- Suburban. May be further divided into 3 types as proposed in [16b] –
  Type A: Hilly/moderate-to-heavy tree density
  Type B: Hilly/light tree density or flat/moderate-to-heavy density
  Type C: Flat/Light tree density.

4.5) RF propagation impairments:

- Path Loss
- Fading (large scale – due to shadowing, small scale- due to multi-path)

- CCI and ACI
- Worst case fading bandwidth and maximum Doppler shift.
- The specification of a precise model of time variability of multi-path is a crucial point.

Based on the measurements given in [13]-[18] the channel model must meet the following requirements:

- Maximum time delay spread of 2 uSec [15], [16a], [14]
- The system should withstand a Doppler shift of more then10 Hz.

5.0 Modulation Formats

- Downstream: 4-16-64QAM
- Upstream: 4-16-64QAM
- Adaptive Modulation & Coding shall be supported in the downstream. The upstream should support different modulation schemes for each user based on the MAC burst configuration messages coming from the base station.

6.0 Frame structure, Timing and Synchronization

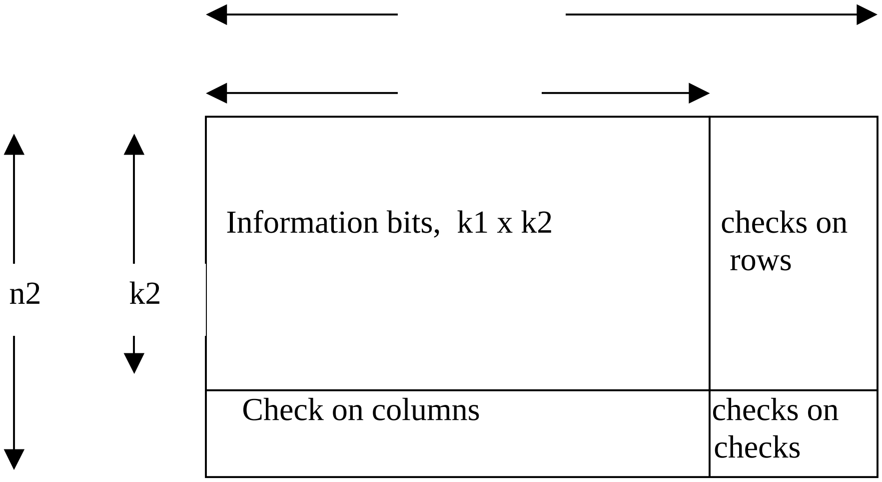
The frame structure will be;

- Dependent on the selection of the Access and Duplexing techniques,
- Related with minimal overhead requirements, timing accuracy requirements and carrier recovery complexity.

Typical value for the downstream frame size is 2-3 msec. (to support AMC)
Values for upstream bursts range from 16 bytes to 1500 bytes (limited by the maximal burst size).

7.0 Channel coding, Interleaving & Scrambling

For the upstream and the downstream Forward Error Correction Codes (FEC) schemes based Block Turbo Codes (BTC) are recommended. The codes recommended for the current standard follows the lines of IEEE802.16.1 MODE B [10]. The general idea of BTC is to use simple component block codes (e.g., binary extended Hamming codes) for constructing large block codes that can be easily decodable by iterative Soft-In \ Soft-out decoder. For the sake of this standard, two-component code are taken to construct a product-code as depicted in the following figure.



Here k1 information bits are encoded into n1 bits by using binary Hamming (n1,k1) code. This process of row-by-row encoding is applied for the first k2 rows. Hereafter, a column-by-column encoding is applied by using (n2,k2) Hamming code until all n1 by n2 matrix representing a codeword is ready.

Simple enhancement techniques are available to adapt block length from a few bytes to very large number of bytes using only few component codes.

The following codes are given as examples:

- Product codes based on shortened binary Hamming code:
  $(2^m - S1, 2^m-m-1-S1, 4)X(2^m - S2, 2^m-m-1-S2, 4)$ where m and S1 and S2 are configurable.
  m=5, S1=2, S2=7 (53+4 bytes for payload)
  m=5, S1=2, S2=8 (53+1 bytes for payload)
  m= 6, S1= 25, S2= 10. (188 bytes for payload)
  m=6, S1=25, S2=9 (188+4 bytes for payload)

  Where, the Hamming codes for m=5 is a (31,26) block code generated by the primitive polynomial
  X^5 + X^2 + 1
  and for m=6 the code is (63,57) block code generated by the primitive polynomial
  X^6 + X + 1

- Product codes based on binary parity-check codes:
  (2k+1, 2k) X (2k+1, 2k) where k is configurable.

Interleaver

Three bit interleaver are recommended. The implementation of the interleaver is by writing the bits into the decoder memory and reading out as follows.

Type 1 (no interleaver) writing row-by-row and reading row-by-row
Type 2 (block interleaver) writing row-by-row and reading column-by-column
Type 3 (permutation interleaver) as in type 2 but with additional row and\or column permutation before reading out the encoded bits.

Scrambler (Randomizer)

The upstream modulator should implement a scrambler with the 15-bit seed value and it will be arbitrarily programmable. A recommended polynomial is: $x^{15} + x^{14} + 1$.

8.0 Dynamic Resource Allocation

TBD

9.0 Power Control

TBD

10.0 Equalizer

For symbol rate of 6 Msymbol/sec or less, and with the maximum delay spread of about 2 usec as reported in [15], [16b], and [13] single carrier modulation with relatively simple Decision Feedback Equalizer (DFE) offers the best performance/complexity tradeoff.

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Appendix 1: IEEE802.16.3 valuation Table

	Criteria	Description	reference
1	Meet IEEE802.16.3 Functional System Requirement (FRD)		[1]
2	Channel Spectrum Efficiency	Support higher order modulation 4-16-64 QAM with high code rate 0.5 to 0.8. Adaptive modulation & coding enables flexible bandwidth allocation to maximize spectral efficiency and overall system capacity.	
3	Simplicity of implementation	Using legacy components and techniques from other standards [2] – [10] and BWA systems. Seamless migration path to more advanced receiver techniques when this technology is available.	
4	STS cost optimization	This critical constraint is achieved by relaxing the requirements on the radio equipment spec – based on single carrier modulation. On the other hand – powerful baseband processing algorithms are applied to meet the FRD.	
5	BTS cost optimization	Focusing on legacy single carrier modulation and advanced BB processing leads to better exploitation of current infrastructure. Simple internetworking to IEEE802.16.1 systems.	
6	Spectrum resource flexibility	Supporting various channelization. Supporting FDD, TDD and FSDD	
7	System service flexibility	Optimized to support variable length IP as well as ATM and MPEG frames. FEC schemes support services which require BER from 10^-4 to 10 ^-9..	
8	Protocol interfacing complexity	TBD	
9	Reference System Gain	TBD	
10	Robustness to interference	TBD	
11	Robustness to channel impairments	Techniques based SC+ DFE allows efficient enhancements of mutipath fading. Flat fading are compensated with AMC including bit interleaver and receiver diversity. DS + DFE are much more robust to Doppler spread.	

12	Robustness to Radio impairments	SC + DFE requires less Peak-to-Average than OFDM systems and are much less sensitive to frequency instability, phase noise, synchronization errors, Doppler spread etc.	