Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**PHY Proposal for IEEE 802.16.3**
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Re:	Response to 802.16.3 Invitation to submit contributions representing proposed PHY Solutions.
Abstract	This proposed PHY addresses the criteria in the Evaluation Table of the Call for Proposals document IEEE802.16.3-00/14 with a flexibly scalable structure that can efficiently respond to the 802.16.3 FRD and allow cost-effective implementations over competitive technologies.
Purpose	To be considered by 802.16.3 Task Group as the 2-11GHz Licensed bands' FWA PHY Solution
Notice	
Release	
Patent Policy and Procedures	

PHY Proposal for IEEE 802.16.3

Introduction

This document gives an outline of the proposed Physical Layer (PHY) for IEEE802.16.3 Broadband Fixed Wireless Access (BFWA) systems in licensed frequency bands from 2-11GHz. This document addresses the criteria listed in the Evaluation Table of the Call for Proposals document IEEE802.16.3-00/14. It incorporates aspects of the IEEE802.16.1 PHY proposals [Foerster00a], to allow reduced equipment cost and to reap the benefits of re-using a proven technology. Single-carrier modulation is proposed to take advantage of this proven technology. Figure 1 shows the wireless access reference model, with SOHO (small office/home office), business and home users communicating with the core network over fixed wireless links.

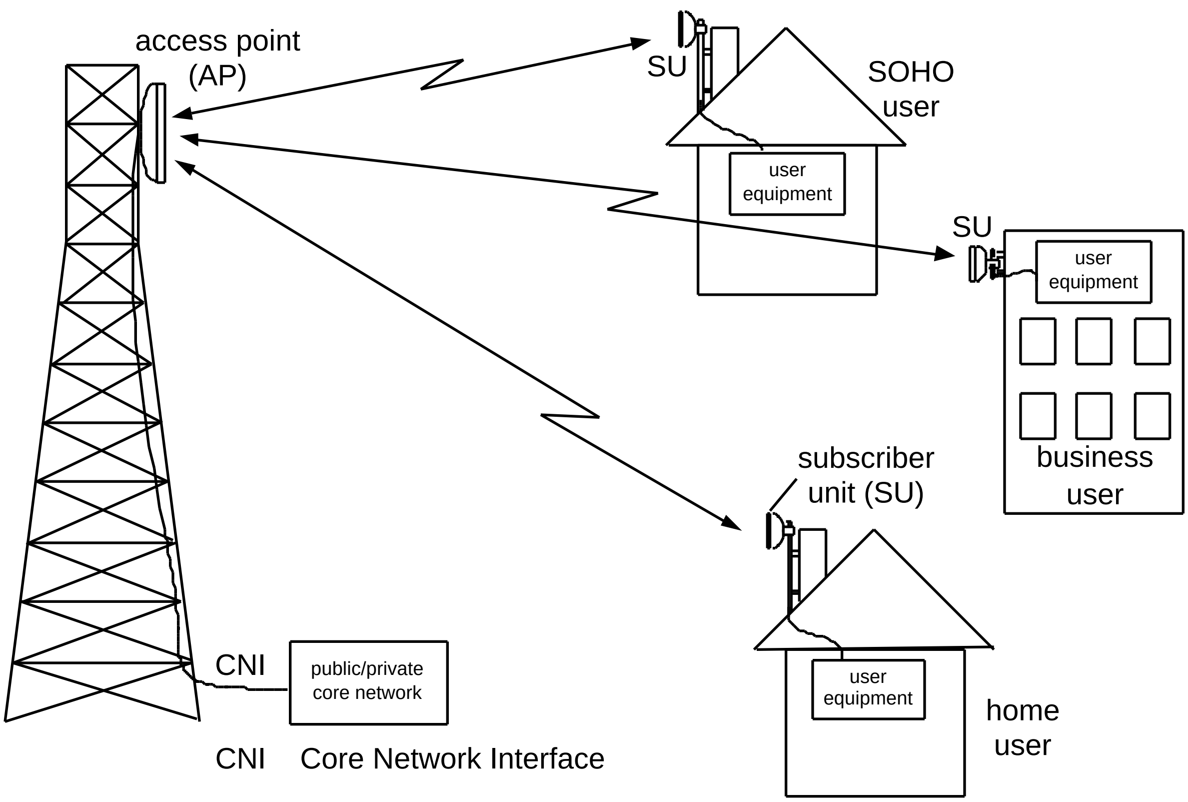

Figure 1 Wireless Access Reference Model

Key Features of the PHY Proposal

The main features of this PHY proposal are a single-carrier modulation scheme with TDMA/DAMA multiple-access, and TDD duplexing. QPSK and QAM constellations, up to 64-QAM, are supported. Hybrid ARQ and variable-rate FEC is proposed for error-correction. Directional antennas combined with equalizers are used to effectively combat multipath.

Multiplexing and Multiple Access Technique

Multiplexing and multiple access is accomplished with time-division (TD) and demand-assigned multiple access (DAMA). Both upstream and downstream channels are divided into a number of timeslots. The MAC layer in the access point (AP) controls the timeslot allocation between different users and for different services. For example, timeslots are allocated for registration, contention or user traffic (uplink), and for control signals and data traffic (downlink).

Duplexing Technique

Time-division duplex (TDD) is used to allow upstream and downstream transmission on a single carrier frequency [Kostas00a]. TDD benefits include efficient statistical multiplexing of bursty sources, as well as dynamic allocation of upstream and downstream capacity. This is an important capability for BFWA systems because some users (e.g.,. residential) in a particular sector may require high downstream capacity for web browsing or video streaming, whilst other users (e.g., SOHO) may require high upstream capacity for web-hosting. TDD allows a mixture of users to be served by the same sector from a single access point (AP), by dynamically allocating upstream and downstream capacity between different users. The TDD frame is divided into a downstream and an upstream subframe, each consisting of a number of slots, as shown in Figure 2. The length of each subframe is controlled on a per-burst basis by the MAC in the AP, thus permitting more efficient response to changes in upstream and downstream traffic changes. A small guard period G_p is used to separate the upstream and downstream subframes. Unlike FDD, which requires duplex frequency spacing, TDD does not require paired frequencies, and so allows more flexible allocation and re-arrangement of channel frequencies. TDD reduces transceiver cost, since only a single radio front-end is needed. Uplink and downlink radio channel reciprocity is a significant advantage of TDD, allowing efficient antenna diversity and pre-coding techniques to be effectively used for reducing multipath.

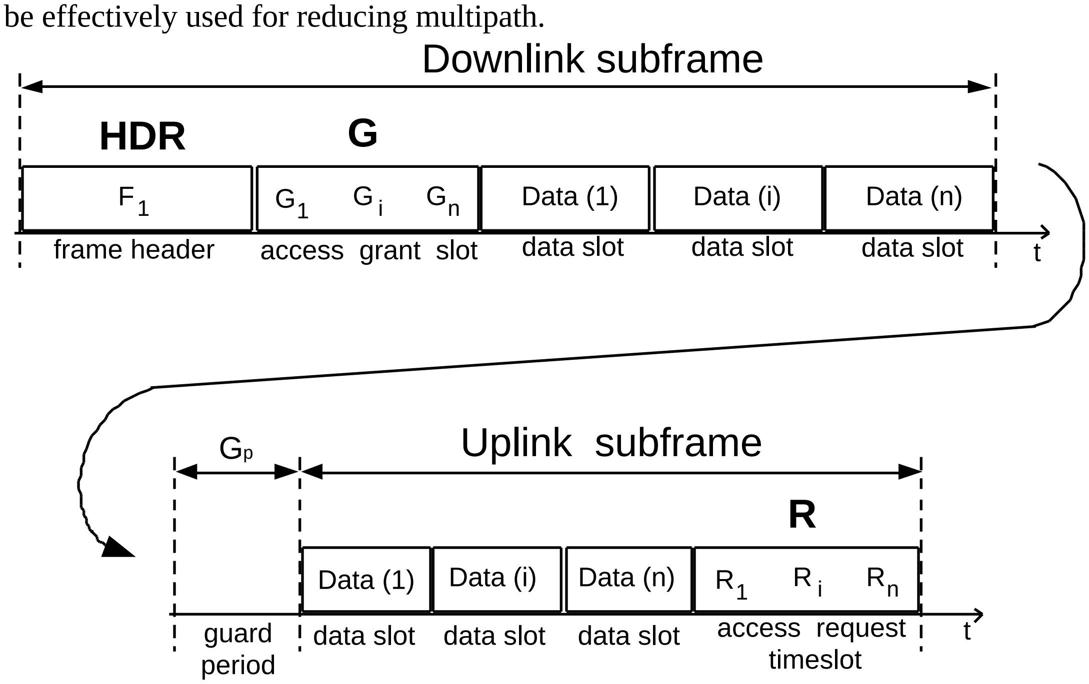

Figure 2 TDD frame showing downstream and upstream subframes

Modulation Scheme

Single-carrier modulation is used on both uplink and downlink. Supported constellations are QPSK, 16-QAM and 64-QAM, with additional support for 8-QAM and 32-QAM. The AP transmits downstream frame headers in the lowest common constellation, typically QPSK. Each frame header contains a preamble to allow subscriber units (SU's) to synchronize with the AP signal. The MAC in the AP selects the appropriate QAM constellation for each SU, based on channel quality and signal strength information.

Coding and ARQ

Data packets use automatic repeat request (ARQ), combined with variable-rate forward error correction (FEC) coding. All timeslots are terminated in a 16-bit cyclic redundancy check (CRC) sequence, which is used at the receiver to generate either a positive acknowledgement (ACK) or negative acknowledgement (NACK). The CRC allows very fast turnaround times of the order of a few _s. On radio channels with high SNR and low delay spread, the FEC block coding is very light, with most of the error recovery being performed with ARQ in the MAC layer. This means that on clear line-of-sight (LOS) channels, FEC overhead is very low. Control signals and ACK packets are much shorter than user data packets, and carry higher FEC overhead. On channels with low SNR or higher delay spread, the MAC increases the FEC loading to provide greater resilience to bit errors and reduce dependence on ARQ. The MAC in the AP uses channel information from each SU to adjust the FEC level for each individual SU. The use of a hybrid ARQ/FEC scheme makes best use of ARQ and FEC for different channels [Matoba98a]. ARQ is very efficient for clear, LOS channels, but throughput drops as the channel degrades. On the other hand, FEC offers good data protection in severe channel conditions, but carries an excessive overhead when the channel conditions are not severe.

Anti-Multipath Techniques

It is proposed that AP use directional antennas with narrow beamwidth in elevation (less than 10^o), but wider beamwidth in azimuth (30^o-60^o) in order to illuminate a wider sector and SU's use narrow-beam spot antennas of 20^o by 20^o or less, to restrict multipath as much as possible. The directional antennas should restrict the rms delay spread to 1μs or less [PorterJW99a], [Erceg99a]. Using a maximum symbol rate of 12.5MHz (T_s = 80ns) gives channel lengths from 10 – 30 symbols at most [Falconer00a]. Time-domain equalization proposed is using a decision feedback equalizer (DFE), as shown in Figure 3, with adaptation using the LMS algorithm. A preamble of length 32 symbols is used on each packet for synchronization. On the downlink, the SU equalizer makes use of the continuous frame headers from the AP to update its coefficients. On the uplink, the AP equalizer may use coefficients from a previous transmission from the same SU, if the time interval between subsequent bursts is short (warm start-up) [Sellars00a]. However, for long time intervals between bursts from a SU, or during random access slots, the equalizer coefficients are re-trained using either a fast start-up LMS algorithm [Sellars99a], or a reduced-complexity RLS algorithm [Cimini96a], [Drewes98a]. A DFE is to be used at both the AP and SU terminals. However, one option to reduce the equalization burden on the AP during random access slots, is to use pre-coding at the SU before transmission [Sellars00b].

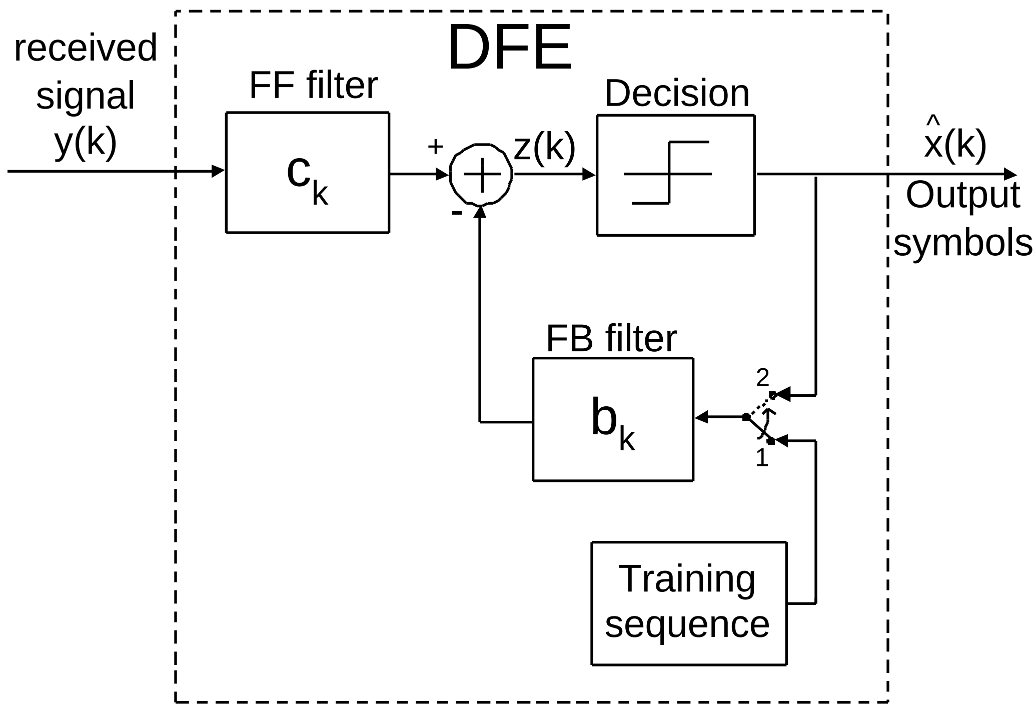

Figure 3 Decision feedback equalizer (DFE) for time-domain equalization

Radio parameters

Single-carrier modulation is much less sensitive to amplifier non-linearities than multicarrier schemes, and the low peak-rms power ratios require less amplifier back-off, particularly for low-order QAM constellations. Single-carrier modulation is less sensitive to frequency-offsets and phase noise than multicarrier modulation. Proposed transmit and receive filters are square-root raised cosine, with roll-off of 0.35

A combination of ARQ as an outer code, and FEC as an inner code, is used to ensure that an error rate of 10^{-10} at the Network Layer is achieved. Two examples are quoted, both using an ARQ outer code with 16-bit CRC. The first uses a Reed-Solomon RS(67,63) inner code, and operates at a raw channel BER of 1.7×10^{-3} . The second example uses a RS(71,63) inner code, and operates at a raw channel BER of 4.3×10^{-3} . Table 1 gives radio parameters for three different QAM schemes:

Table 1 Radio parameters

Modulation scheme	Bandwidth efficiency (Bps/Hz)	Peak-rms power (dB)	SNR for channel BER = 1.7×10^{-3} ARQ and RS(67,63) (dB)	SNR for channel BER = 4.3×10^{-3} ARQ and RS(71,63) (dB)
QPSK	2	2.4	10.3	9.4
16-QAM	4	3.4	17.0	16.1
64-QAM	6	3.7	23.0	22.0

In the bands 2-11GHz, three likely bands have been addressed: 5GHz band, MMDS band (2.4GHz) and the European WLL band (3.5GHz) band. Each band will have different channelization and data rates. Some examples are given in Table 2.

Table 2 Likely bandwidths and symbol rates for different frequency bands

Frequency Band (GHz)	Symbol rate (MHz)	Channel BW (MHz)
2.4	4.2	6
3.5	2.1	3.5
5	12.5	15

Table 3 shows the gross bit rates, as well as effective data rates assuming a MAC efficiency of 80% (typical figure for ARQ only), for each of the different modulation schemes in the different frequency bands.

Table 3 Gross and effective data rates

Modulation scheme	Gross bit rate (Mbps)			Effective data rate (Mbps)		
	2.4GHz	3.5GHz	5GHz	2.4GHz	3.5GHz	5GHz
QPSK	8.3	4.2	25	6.6	3.3	20
16-QAM	16.7	8.3	50	13.4	6.7	40
64-QAM	25	12.5	75	20	10	60

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