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Title	**Addendum to IEEE802.11a PHY for WirelessHUMAN™ Standard**
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Re:	Call for Contributions for Modifications of 802.16 MAC and 802.11a - HIPERLAN/2 PHY for the WirelessHUMAN™ Standard: Documentation Number IEEE 802.16.4-00/01
Abstract	More functionality is needed in addition to IEEE802.11a PHY in order to provide for the TDD/TDMA mode as specified on IEEE802.16.1 MAC for Mode B upstream data. This is particularly important to support the jitter and latency sensitive IP packets such as VoIP.
Purpose	To identify the deficiencies of the 802.11a PHY in supporting key system characteristics and to modify the physical layer specification accordingly for the WirelessHUMAN™ standard.
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Amendments to 802.11a PHY for WirelessHUMAN™ Standard

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Introduction

This document gives an outline of the proposed changes to the Physical Layer (PHY) for WirelessHUMAN™ Broadband Fixed Wireless Access systems in un-licensed frequency bands in sub-10GHz. This document addresses the criteria listed in the Call for Proposals document IEEE 802.16.4-00/01. It discusses functions that are needed in addition to what is available in the IEEE802.11a PHY to support a TDD/TDMA mode of operation in Metropolitan Area Networks. This addendum addresses the requirements necessary for the PHY to support QoS (Quality of Service) for the jitter and latency sensitive IP packets such as VoIP. The discussion topics address support for Mode B operation, which is specified in the IEEE802.16.1 MAC.

Number of subcarriers per OFDM symbol

For a given RF bandwidth, as the number of subcarriers per OFDM symbol increases, the signal is more immune to multipath but suffers increases in jitter and latency. The new WirelessHUMAN™ must support longer communication distances (as compared to the 802.11a environment) and the jitter and latency requirements of VoIP packets. Therefore choosing the optimum number of subcarriers is essential to the performance of the system. Fifty-two (52) subcarriers may be too small to be effective in combating multipath, and it is proposed that this be changed to a maximum of 256.

Differential Encoder/Decoder

Using a differential encoder/decoder at the expense of approximately 2dB E_b/N_o loss at the receiver provides a very cost effective and robust OFDM receiver for Subscriber Stations (SS) by eliminating the channel estimation requirement or the precise alignment of symbol timing for decoding OFDM symbols. For the Base Station (BS) receiver this mode provides a shorter preamble for upstream data.

Burst mode upstream packet format

Preamble (1 OFDM symbol)	Payload (Variable number of OFDM symbols)

Figure 1. Upstream packet structure

The PLCP (Physical Layer Convergence Protocol) preamble (SYNC) for IEEE802.11a is equivalent to 4 OFDM symbols. Ten (10) short symbols (equivalent to two normal OFDM symbols) are used for Signal Detect, AGC, Diversity selection, Coarse Freq. Estimation and Timing Synchronization, and a long symbol (equivalent to two OFDM symbols) for fine acquisition. This is needed for CSMA/CA MAC Protocol because all listeners (SS s) must synchronize to the sender. This long preamble may not be necessary for the frame-based point to multipoint system in the downstream path since the downstream data repeats on every frame. It is also not suitable for the upstream data as the latency introduced by this preamble is excessive for real time traffic.

The proposed upstream preamble is limited to one OFDM symbol and is attached at the beginning of each payload by a subscriber station as shown on Figure 1. The preamble is used for channel estimation and is used as phase reference for differential detection. Another advantage of this approach is that it removes stringent receive gain control requirement of BS receiver to support QAM.

Upstream modulation

It is proposed that the upstream modulation be limited to PSK for several reasons. One, it is very difficult to provide the near constant amplitude for each subscriber station data packets to support QAM on the upstream TDMA path especially for noise-like OFDM signals. In addition, the limited power requirement on UNII band may further prevent the accurate level setting. Second, by using PSK and differential detection in the upstream path it is possible to reduce the built in latency of the PHY/MAC layer to levels acceptable for voice and video transmission.

It is possible to support multilevel QAM in the upstream by prolonging the SS preamble such that AGC at the BS can quickly adjust to the desired level and correct the phase. The benefits achieved by adding this additional complexity are questionable, since the spectral efficiency gain is lost by the extra overhead for channel synchronization, not to mention the increased latency caused by prolonged preamble.

Upstream power control

Upstream output power from each SS is controlled by the BS to maintain a near-constant amplitude at the BS. This is important to minimize the amplitude fluctuations caused by propagation path loss, which can vary up to 70 dB in dynamic range. Power is controlled by the BS by commanding each SS to increase/decrease the power.

Each subscriber station synchronizes to the base station and derives both carrier frequency and the output reference clock from the downstream data. Therefore only propagation delay correction is needed for upstream data to synchronize accurately to the upstream time slot. This is supported through a ranging calibration procedure and needs to be amended to IEEE802.11a.

Ranging and upstream timing synchronization

For TDMA upstream, it is crucial that each SS must transmit its packet at the proper BS time slot. A ranging process is needed by each SS to transmit a packet ahead of time to compensate for the propagation delay. Dedicated channels (can be pilot channels) can be used to measure the propagation delay between SS and BS.

Downstream modulation

Downstream subcarrier modulation is expanded to support both 16/64 QAM and N-ary PSK. Since the frame repeats every fixed period, good channel estimation can be obtained with relatively short preamble for coherent or pseudo-coherent demodulation. Further, the amplitude variation from a packet to another is non-existent at SS receiver.

The downstream modulation also supports the differential mode for PSK. The trade off between differential and coherent design will be the implementation cost versus performance, with the QAM approach adding significantly to the cost and the complexity of the SS.

Convolutional encoder with tailed-off

The burst mode convolutional encoder with tail-off is proposed and each burst ends within one OFDM symbol. For instance, 96 subcarriers with QPSK modulation will send 192 coded bits with tailed-off. The tailed-off operation is completed by inserting all zeros to the encoder state. The constraint length 5, rate _ encoder is supported for normal operation. In addition rate 2/3 and _ punctured modes are also supported.

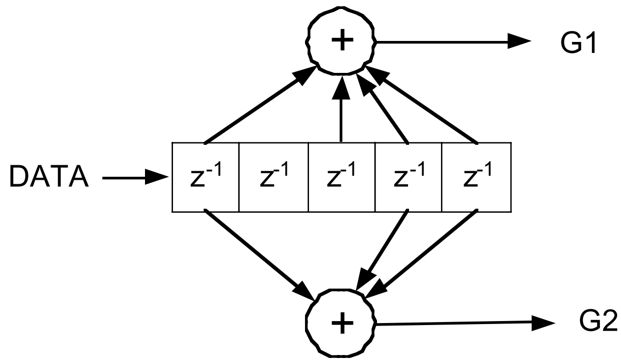

Figure 2. Convolutional encoder

Interleaver

A depth of 12 is used for the interleaver per OFDM symbol. Figure 3 depicts the method of interleaving for a 96 subcarrier system.

Data Flow

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64
65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88
89	90	91	92	93	94	95	96

Input

Data Flow

1	9	17	25	33	41	49	57
65	73	81	89	2	10	18	26
34	42	50	58	66	74	82	90
3	11	19	27	35	43	51	59
67	75	83	91	4	12	20	28
36	44	52	60	68	76	84	92
5	13	21	29	37	45	53	61
69	77	85	93	6	14	22	30
38	46	54	62	70	78	86	94
7	15	23	31	39	47	55	63
71	79	87	95	8	16	24	32
40	48	56	64	72	80	88	96

Output

Figure 3. Interleaver

When the subcarriers are modulated with 16QAM or 16PSK, an OFDM symbol with 96 subcarriers carries up to 384 bits of information. The 384 bits are broken into 4 segments of 96 bits and each segment is interleaved. Each row of the interleaved 4 segments is being modulated as shown on Figure 4.

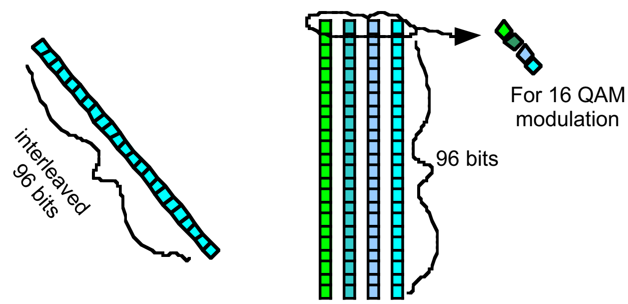

Figure 4. Bit order for 16 QAM

The purpose of the interleaver is to randomize the burst error associated with the frequency selective fading in an OFDM system to get the optimum performance of the Viterbi decoder. This type of decoder provides the best performance in a random error environment. On the contrary, Reed-Solomon code is well suited for burst error, hence the randomizing could cause worse performance. Therefore, the interleaver must be disabled when the convolutional encoder is bypassed.

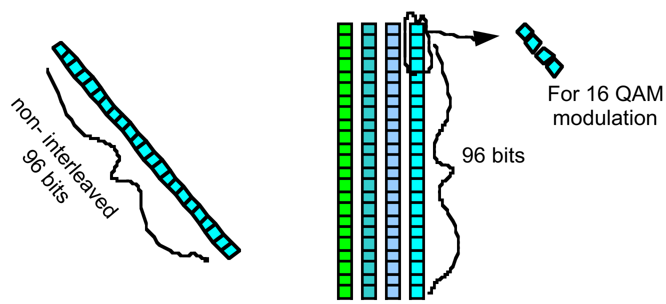

Figure 5. Bit order for 16QAM on bypass mode

Summary

The CSMA/CA optimized IEEE802.11a PHY lacks a few important functions which a centralized MAC protocol such as the IEEE802.16.1 MAC requires if it is to support real-time traffic. These are:

- Ranging
- Power control
- Frame based synchronization by SS to support TDMA efficiently

The goal of supporting the above functions, is to enable the system to provide centralized RF bandwidth allocation and scheduling such that it can provide different grades of QoS, specifically for jitter and latency sensitive IP packets such as VoIP.

The following table summarizes the proposed changes to the existing 802.11a PHY for the Wireless HUMAN standard.

	Downstream (BS to SS)	Upstream (SS to BS)
Multiple access	TDD/TDM	TDD/TDMA
Ranging	N/A	Must be aligned accurately to BS time slot
Power Control	N/A	Must be within amplitude tolerance of BS demodulator
Number of subcarriers	< 256	< 256
Subcarrier modulation	64QAM, 16QAM, QAM 16PSK, 8PSK, QPSK	16PSK, 8PSK, QPSK
Differential Enc/Dec	Time domain differential (On/Off)	Time domain differential (On/Off)
FEC	Dynamically variable FEC coding per IP flow	Dynamically variable FEC coding per IP flow
Inner code	Convolutional encoder with tail-off K=5, rate = _, 2/3, _ or bypass	Convolutional encoder with tail-off K=5, rate = _, 2/3, _ or bypass
Outer code	Shortened Reed Solomon code with GF(2^8), t= 0..16	Shortened Reed Solomon code with GF(2^8), t= 0..16
Interleaver	Frequency domain interleaver. No interleave if convolutional code is bypassed	Frequency domain interleaver. No interleave if convolutional code is bypassed

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