Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	Outline of PHY Proposal for MMDS Communications
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Re:	Proposal submitted in response to Call for proposal on PHY specifications in IEEE 802.16.3 on 2000-9-15
Abstract	This document presents the outline of the PHY specifications for the Enhanced OFDM (EOFDM) and enhanced QAM (EQAM). The proposed PHY supports OFDM and QAM modulation with anaptive modulation and FEC on upstream and EOFDM with adaptive modulation on the down stream.
Purpose	Contribution as a proposal for consideration as the PHY layer specifications for 802.16.3.
Notice	
Release	
Patent Policy and Procedures	

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Proposal for Unified PHY for MMDS Communication

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1. Overview

The PHY layer in the MMDS system architecture is responsible for signal processing functions including modulation, demodulation, forward error correction etc on both the down stream and upstream data transfers between the base station (head end) and the consumer premise equipment (CPE). The goal of having a standardized system is to have total interoperability between the CPE's and the head end equipment.

There are two basic modulation schemes that have been considered for wireless data transfer: QAM (Quadrature Amplitude Modulation) and OFDM (Orthogonal Frequency Division Multiplexing). Several variations of both methods have been proposed.

In general, it is accepted that the QAM technique allows for greater throughput while the OFDM technique results in more robust performance when a clear line of sight is not available between the transmitting and receiving antennas.

In field trials, OFDM was shown to be more robust in terrestrial reception of digital transmission than QAM based system, and thus can provide better coverage for the MMDS service.

The OFDM scheme also is well suited for digital communication where data is delivered in bursts. Data delivery in communication systems, which is combined of concatenated packets of bytes, is naturally matched into the cyclic nature of the OFDM transmission. Demodulation and decoding is better served by OFDM for the multi-user structure of the MMDS system.

However, the OFDM transmission format includes significant redundancy in the form of a guard interval (12% to 25%) and pilot sub-carriers (12% to 26%). This reduces the capacity of the OFDM modulation compared to the more traditional QAM based system.

Some of this limitation may be removed by using Enhanced QAM modulation (EQAM). EQAM, is designed for QAM modulation application with terrestrial signal.   The EQAM incorporates a training signal that greatly improves the equalization capability of the channel. The training signal is inserted in a repetitive cyclic order at about 2% duty cycle thus preserving the high capacity of the QAM modulation while improving the equalization performance.

In a typical MMDS deployment, customers having a clear line of sight to the transmitting antenna may be able to get higher connect speeds than those out of the line of sight. However, with a fixed modulation scheme, the system must be set up for the worst-case scenario. Adaptive modulation and adaptive FEC are ways to provide better coverage for distance CPEs while enhancing data delivery rate to nearby CPEs.

The OFDM system based on adaptive modulation and adaptive forward error correction is called enhanced OFDM (EOFDM).

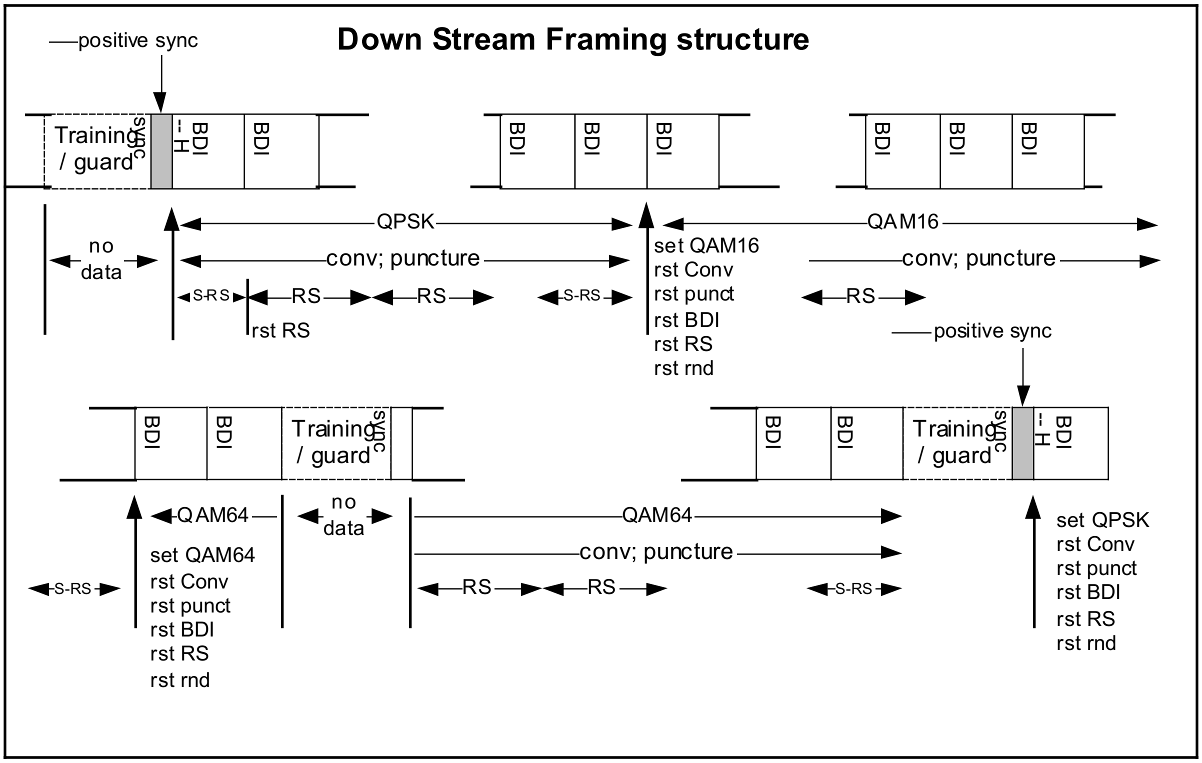
2. Outline of Proposed PHY

This section summarizes the proposal. The downstream data should be in OFDM format with adaptive modulation (EOFDM). The upstream data may be in EOFDM or QAM with training signals (EQAM).

2.1 Down Stream

1. The structure of data stream is OFDM.
2. A frame in EOFDM is based on the natural framing of the OFDM symbol.
3. A Sframe is constructed of a fixed number of frames.
4. The header at the start of a Sframe contains the structure of the data to follow in the next Sframe. The header is placed only at the start of a Sframe.
5. The structure of data in each super frame is as follows:
    a. Data sections are constructed from whole blocks of Bit Interleaves.
    b. QPSK header – 15 bytes of data
    c. Continuing modulation from last Sframe
    d. QPSK data
    e. QAM16 data
    f. QAM64 data

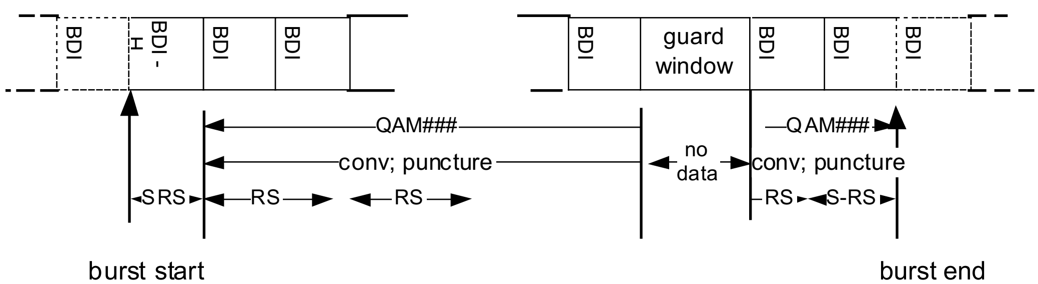
6. The header should contain the following information in RS(15,6) encoded:
    a. [length; puncture; reserved bits] – for continuing from last Sframe
    b. [length; puncture; reserved bits] – for QPSK
    c. [length; puncture; reserved bits] – for QAM16
    d. [length; puncture; reserved bits] – for QAM64
    e. 2 bytes for system use:
        i. RS mode (N,T)
        ii. Bit interleaving mode
    f. 6 bytes parity bytes for RS (t=3)
    g. The header can be extended to 2BI blocks thus providing RS(30,6) for direct data delivery to the receiver PHY (D/A gain).
7. The FEC in each sections includes:
    a. RS codes (204, 16)
    b. Randomizer
    c. Convolutional code (K=7) with puncture:1/2, 2/3, _, ,5/6, 7/8.
    d. BI (bit interleaving) – programmable length block interleaver.
    e. QAM gray coding



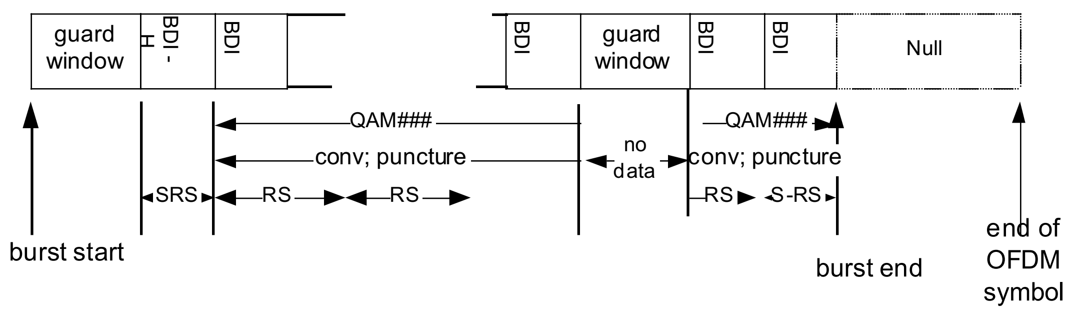
2.2 Up Stream

1. EQAM/OFDM burst includes only single modulation sections.
2. OFDM burst is in data carrying sub-carriers preceded by a header.
3. The Up stream header and RA format.
    a. [length, puncture; modulation]
    b. RA 6 bytes
4. OFDM/EQAM - Up stream clock rate is always a $1/2^n$ of the down stream clock rate.

Up Stream OFDM Framing structure - synched system



Up Stream OFDM Framing structure - non sycnhed system



2.3 Duplexing

They PHY supports FDD operation.

1. Two channels are allocated: one for the upstream and the second for down stream.

2. Transmission of the down and upstream is allowed at the same time.

2.4 Antenna Diversity

The PHY should support multiple antenna input and output (MIMO).

2.5 MAC Compatibility

The PHY should be compatible with both DOCSIS and 802.16 based MAC layers and should include support ARQ in the MAC layer.

3. Advantages of the proposed PHY

1. Downstream OFDM transmission results in robust coverage in non-line of sight situations.

2. Adaptive modulation on the downstream allows for higher data rates for users with good line of sight while maintaining robust service to users with non line of sight.

3. Only one mode (OFDM) of downstream transmission ensures interoperability of base station with various CPE’s.

4. Choice of Single Carrier or Multicarrier upstream channels allows optimization of upstream throughput and robustness.

5. Adaptive modulation on upstream (OFDM and QAM) results in optimized data rates depending on signal strength.

4. Relation to existing standards

QPSK and QAM 16/64 modulation follows ITU-T, J.83, Annex A/C .