Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**	
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Abstract	The IEEE 802.16 Working Group on Broadband Wireless Access is developing the IEEE 802.16 WirelessMAN™ standards for Wireless Metropolitan Area Networks. These standards, covering licensed and license-exempt bands from 2-66 GHz worldwide, are creating a firm foundation for the development of the industry. This article was submitted to *EE Times*. An article based on it was published as "IEEE Takes On Broadband Wireless, Roger B. Marks, *EE Times* 1169, pp. 78-108, June 4, 2001." <http://www.eetimes.com/printableArticle?doc_id=OEG20010606S0008>	
Purpose	This document provides an overview of IEEE 802.16 activities from the Chair's perspective.	
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IEEE 802.16 Standards Crystallize the Fixed Broadband Wireless Access Industry

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Abstract

The IEEE 802.16 Working Group on Broadband Wireless Access is developing the IEEE 802.16 WirelessMAN™ standards for Wireless Metropolitan Area Networks. These standards, covering licensed and license-exempt bands from 2-66 GHz worldwide, are creating a firm foundation for the development of the industry.

1.0 Introduction

Broadband wireless access (BWA), like any other segment of the information technology industry, thrives on interoperability standards. In the cases of data communications networks, the IEEE 802 LAN MAN Standards Committee of the Institute of Electrical and Electronics Engineers, Inc. (IEEE) has become the world leader in local area networks (LAN) and metropolitan area network (MAN) standards. Thanks to its organization, processes, and culture, it has a history of turning technology into economic success. The success of the IEEE 802.3 Ethernet standard and the IEEE 802.11 Wireless LAN standard are stunning examples of the power of 802's open industry con-

sensus process. The BWA industry is following a similar path through the IEEE 802.16 Working Group on Broadband Wireless Access, which is developing the IEEE 802.16 WirelessMAN™ standard for Wireless Metropolitan Area Networks. This standard, covering licensed and license-exempt bands from 2-66 GHz worldwide, is creating a firm foundation for the development of the industry.

After some intial organization efforts dating back to 1998, Working Group 802.16 began its work in July 1999. Hundreds of people have participated in the bimonthly weeklong meetings. The Group currently has 200 Members and official Observers from over 100 companies. Its work has been closely followed; for example, the IEEE 802.16 web site <http:// WirelessMAN.org> handled over 2.8 million file requests in the year 2000.

IEEE 802.16 addresses "first-mile" applications of wireless technology to link commercial and residential buildings to high-rate core networks and thereby provide access to those networks. 802.16's work has primarily aimed at a point-to-multipoint topology with a cellular deployment of base stations, each tied into core networks and in contact with fixed wireless subscriber stations. The subscriber stations typically include rooftop-mounted antenna/ radio units connected to indoor network interface units, although in some cases both units could be indoors or both outdoors. Initial work has aimed at businesses, with much of the market focus on small-to-medium-sized enterprises. Attention has increasingly turned toward residential opportunities, particularly as the lower frequencies have become available for two-way service.

Working Group 802.16 is currently completing a draft of the IEEE 802.16 Standard Air Interface for Fixed Broadband Wireless Access Systems. This document includes a flexible medium access control layer (MAC). The accompanying physical layer (PHY) is designed for 10-66 GHz, informally known as Local Multipoint Distribution Service (LMDS) spectrum. The standard is not yet final, but the draft is stable and has passed Working Group Letter Ballot, pending resolution of comments proposed to improve it. Publication is planned for late 2001.

Simultaneously, the Working Group is developing amendments to the base 802.16 standard to accomodate lower frequencies. Amendment 802.16a will address licensed bands from 2-11 GHz; the primary target in the U.S. is the Multichannel Multipoint Distribution Service (MMDS) bands. Amendment 802.16b aims at the needs of license-exempt applications around 5-6 GHz, sometimes known as U-NII bands.

Prior to the publication of its air interface, the Working Group will publish the *IEEE 802.16.2 Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems,* which concentrates on 23.5 to 43.5 GHz. This document has been balloted and is scheduled for final approval in June 2001. Extensions to the lower frequencies are under consideration.

IEEE 802.16 maintains a close working relationship with standards bodies in the International Telecommunications Union and ETSI, particularly with the HIPERACCESS and HIPERMAN programs of ETSI's Broadband Radio Access Networks (BRAN) project and with ETSI Working Group TM4.

2.0 802.16 MAC

The 802.16 Working Group follows the traditional 802 approach of developing multiple PHY options supported by a common MAC. Although the service requirements of the three air interface projects differ, 802.16 MAC (Figure 1) is flexible enough to support, with extensions, all of

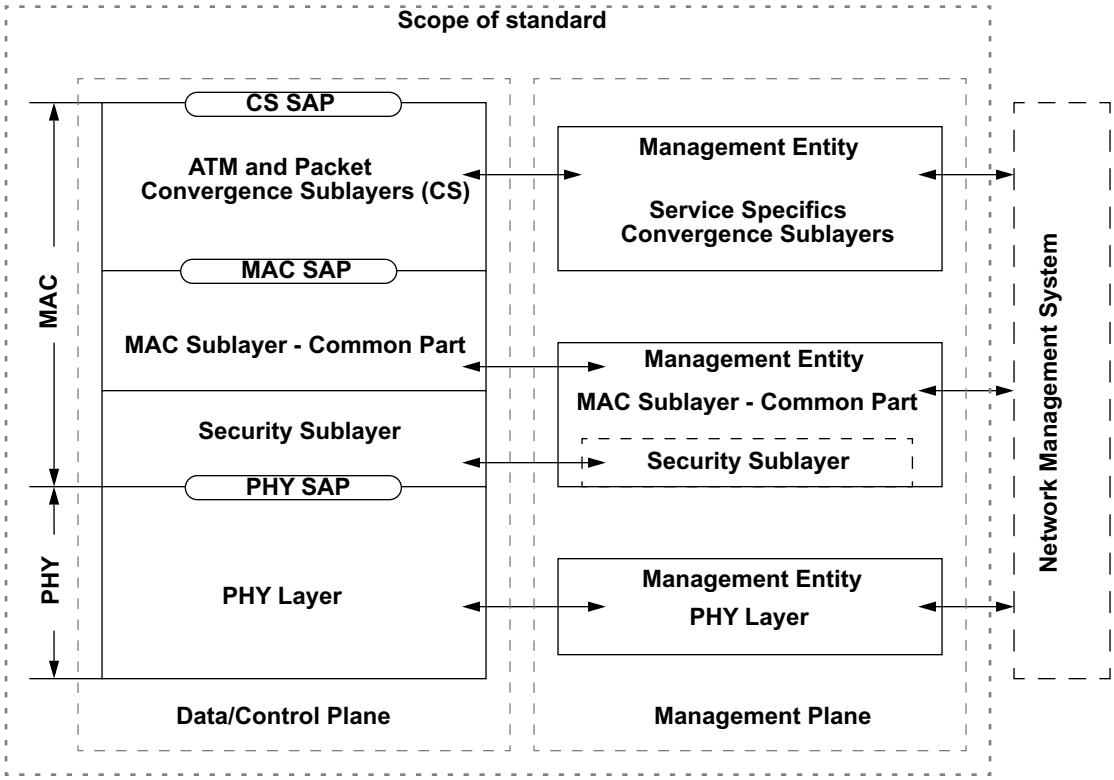

FIGURE 1. IEEE 802.16 Reference Model and Protocol Stack

them.

In general, the point-to-multipoint architecture assumes a time-division multiplexed (TDM) downlink from the base station, with subscriber stations in a given cell and sector sharing the uplink, typically by time-division multiple access (TDMA). Uplink access is controlled by the base station, which has a set of scheduling mechanisms at its disposal for optimizing system performance.

The MAC draws from the Data-Over-Cable (DOCSIS) standard that has been successfully deployed in hybrid-fiber coaxial (HFC) cable systems, which have a similar point-to-multipoint architecture. However, the MAC protocol engine is a new design. It is a connection-oriented MAC able to tunnel any protocol across the air interface with full Quality of Service (QoS) support. Asynchronous Transfer Mode (ATM) and packet-based convergence layers provide the interface to higher protocols. While extensive bandwidth allocation and QoS mechanisms are provided, the details of scheduling and reservation management are left unstandardized and provide an important mechanism for vendors to differentiate their equipment. A privacy sublayer provides both encryption and authentication.

An important MAC feature is the option of granting bandwidth to a subscriber station rather than to the individual connections it supports. This provides the option of allowing a smart subscriber

station to manage its bandwidth allocation among its users. This can make for more efficient allocation in multi-tenant commercial or residential buildings. Efficiency is also enhanced by the provision for header suppression, concatentation, fragmentation, and packing.

3.0 802.16 Physical Layers

3.1 LMDS

The 10-66 GHz PHY assumes line-of-sight propagation with no significant concern over multipath propagation. Two basic modes are provided. The Continuous Mode uses frequency division duplexing (FDD), with simultaneous uplink and downlink on separate frequencies. A continuous time division multiplexed downstream allows a powerful concatenated coding scheme with interleaving. The Burst Mode allows time division duplexing (TDD), with the uplink and downlink sharing a channel but not transmitting simultaneously. This allows dynamic reassignment of the uplink and downlink capacity. This mode also allows "Burst FDD," which supports half duplex FDD subscriber stations that do not simultaneously transmit and receive (see Figure 2) and may therefore be less expensive. Both TDD and Burst FDD support adaptive burst profiles in which modulation (QPSK, 16-QAM, or 64-QAM) and coding may be dynamically assigned on a burst-by-burst basis. This real-time trade-off of capacity versus robustness again offers to vendors opportunities to implement sophisticated algorithms to differentiate their approach while retaining interoperability.

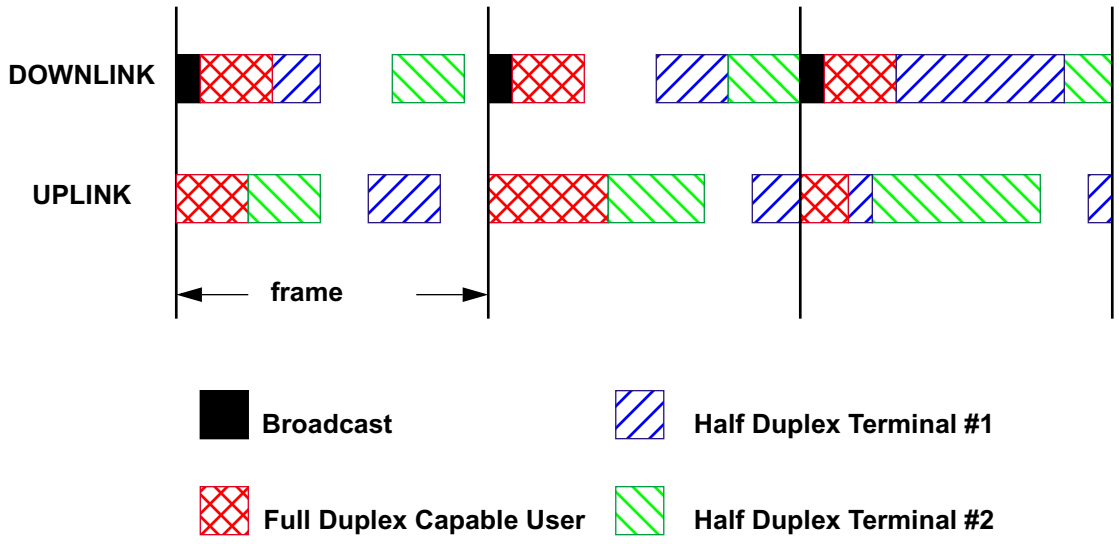

FIGURE 2. Example of Burst FDD Bandwidth Allocation

The choice of Continuous or Burst Mode may depend on the available channel allocations and other regulatory issues. Because the standard is intended for worldwide use, the channelization is left flexible. Recommendations are included, however. These suggest symbols rates of 20 MBaud in a 25 MHz channel, which, assuming 64-QAM, translates to data rates as high as 120 Mbit/s in that channel.LMDS operators typically have access to many such channels and may reuse them in several sectors per cell site.

3.2 Licensed Bands, 2-11 GHz

802.16 has been developing a standard for 2 to 11 GHz BWA. In the U.S., the primary targeted frequencies are in the MMDS bands, mostly from 2.5-2.7 GHz. Worldwide, 3.5 GHz and 10.5 GHz are likely applications. Because non-line-of-sight operation is practical and because of the lower component costs, these bands are seen as good prospects for residential and small-business services. The spectrum availability is suitable to these uses. 802.16 has decided to support both single-carrier and multicarrier PHY options. The single-carrier proposal, submitted by staff of 16 companies, uses frequency-domain equalization. The multicarrier proposal, submitted by staff of 17 companies and an industry consortium; use orthogonal frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA). Both support TDD and FDD; the detailed proposals are on the web. MAC enhancements are also under development. Final approval of this amendment is planned for March 2002, but a stable draft is expected months earlier.

3.3 License-Exempt Bands, 5-6 GHz

In the case of license-exempt bands, 802.16 is tasked to develop a physical layer based on the 802.11a OFDM and/or HIPERLAN/2 PHYs. Coordination of base stations under independent operators in unlicensed spectrum is an important issue facing this group. MAC enhancements under development include an optional mesh architecture in addition to the point-to-multipoint topology; this is testimony to the flexibility of the 802.16 MAC. Final approval is scheduled for March 2002.

4.0 Perspective

IEEE 802.16 represents an broad industry commitment to develop interoperable equipment for fixed broadband wireless access. The challenging effort of creating high-quality standards began in 1999. Good standards take time, but 802.16 has demonstrated its ability to move quickly. The time spent in refining IEEE standards is not wasted because it is applied to solving technical problems and consolidating innovations. The result is the crystallization of standards that define the next generation of equipment, not the past generation. With the consensus participation of the industry, these standards are set to define a major new alternative method of broadband access.

5.0 About the Author

Roger B. Marks has been the Chair of IEEE 802.16 since its inception. He received his A.B. in Physics in 1980 from Princeton University and his Ph.D. in Applied Physics in 1988 from Yale University. A Fellow of the IEEE, he is with U.S. Commerce Department's National Institute of Standards and Technology (NIST) in Boulder, Colorado, USA.