Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Media Access Control Protocol Proposal based on ETSI DVB (EN 301 199)**
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Re:	802.16 Medium Access Control Task Group CALL FOR CONTRIBUTIONS - Session #4, Document 80216m-99_01
Abstract	This MAC proposal is based on an ETSI specification (EN 301 199) developed specifically for LMDS systems. The solution provides an interaction channel for LMDS networks as part of a wider set of alternatives to implement interaction services for digital video broadcasting (DVB) systems.
Purpose	The author desires that the 802.16 working group incorporate all or part of the proposal into the 802.16.1 standard.
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Media Access Control Protocol Proposal based on ETSI DVB (EN 301 199)

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Introduction

This media access control (MAC) proposal is based on an ETSI specification (EN 301 199) developed specifically for LMDS systems[1] The solution provides an interaction channel for LMDS networks as part of a wider set of alternatives to implement interaction services for digital video broadcasting (DVB) systems. The interactive channel is usable for delivery of broadband data and telephony transport services even if video is not delivered over the system.

The specification defines a MAC for delivery of high-bandwidth voice, date, and video services. Services under consideration include telephony, asynchronous transfer mode (ATM), video, video conferencing, T1/frame relay equivalent, and many others.

The intended services allow transparent bi-directional transfer of ATM and Internet Protocol (IP) traffic between network access points and customer locations over a point-to-multipoint (P-MP) microwave radio system.

Overview of functions and interfaces

Include an overview that describes functions, including interfaces to other layers.

ITU-T Recommendation J.112[2] contains three approaches for providing interactive cable television services (Figure 1). Appendix A contains a European centric DVB/DAVIC[3] approach as documented in ETSI specification EN 301 199. Appendix B contains a North American approach based on MCNS/DOCSIS[4]. Appendix C contains an approach used in Japan.

An excellent comparison of the DVB/DAVIC versus MCNS/DOCSIS is available on the web.[5]

The proposed MAC supports TDMA in the upstream path and MPEG-2 transport streams downstream. The frame structure and burst formats are tailored for the fast packet approach of ATM cells. These features enable implementation within the radio of a multiplexing function with relatively small and deterministic delay. The implementation of a deterministic multiplexing function is a key capability of advanced P-MP radios that are used to provide services with guaranteed QoS requirements. The ability to perform muliplexing is key to allowing the air interface to provide a “pair-gain”, i.e. the radio system has many more possible subscriber (lines) than instantaneous subscribers at the network connection (trunks).

An alternative to an ATM based mid-layer protocol is to directly transport IP packets on top of the MAC as done with a MCNS/DOCSIS approach. Because of the variable packet length of IP packets, the IP-based approach results in a probabilistic delay. The average delay can be reduced by increasing the data rate, which also requires increased bandwidth. But in cases where the available bandwidth is limited, such as it is with a licensed block of radio spectrum, it is not possible to increase the data rate to arbitrarily large rates in order to meet QoS requirements. The author submits that a fast packet mid layer protocol, such as provided with ATM, is necessary to meet the service requirements for broadband wireless access (BWA) systems that may carry telephony, video, and data services, simultaneously.

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[1] European Telecommunications Standards Institute, “Digital Video Broadcast (DVB); Interaction channel for Local Multi-point Distribution Systems (LMDS), EN 301 199 v1.2.1 (1999-06), available at www.etsi.org.

[2] International Telecommunications Unions, Telecommunications Sector, “Series J: Transmission of Television, Sound, Programme and other Multimedia Signals, Interactive systems for digital television distribution, J.112 (3/98).

[3] DVB/DAVIC – Digital Video Broadcasting/Digital Audio Video Council.

[4] MCNS/DOCSIS – Multimedia Cable Network Services/Data Over Cable Service Interface Specification

[5] “Overview of DVB-RCCL/DAVIC vs. MCNS/DOCSIS,” http://www.ebu.ch/dvb/dvb_articles.

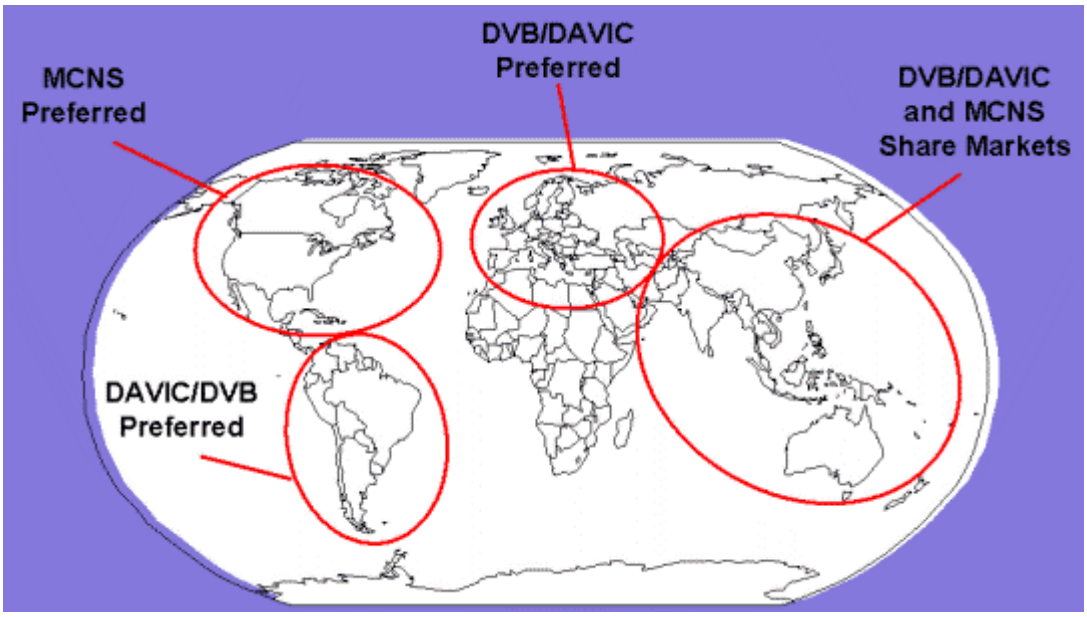

Figure 1, Regional Usage of various Cable Modem Approaches.[6]

The DVB/DAVIC MAC is tailored to efficiently transport asynchronous transfer mode (ATM) mid-layer protocols. The MCNS MAC is tailored to efficiently transport Internet Protocol (IP) without an ATM layer.

The bi-directional interaction network is generally separate from the high-bandwidth downstream broadcast network. However, the downstream interaction channel can be embedded in the MPEG-2 transport stream of the broadcast channel and as such is called “inband signaling” (IB). The downstream channel can also be a DVB-MS channel specifically for the interaction network and as such is called “out of band signaling” (OOB). The OOB signaling protocol is per ETS 300 800 and uses 70-130 MHz downstream and 5-65 MHz upstream. The IB signaling has three spectrum plans which use 950-2150 MHz downstream and 5-65, 5-305, or 400-700 MHz upstream.

The downstream path provides synchronization and information to the NIU.

The upstream path uses time division multiple access (TDMA). The transmit start time is synchronized to a common source and accommodates deviations in propagation delay. Four access modes include fixed rate, dynamic, contention, and ranging.

A continuous upstream path can also be implemented.

One downstream channel is used to synchronize up to eight upstream channels.

Three access modes are possible: one connection oriented and two connectionless.

A 48-bit MAC address is used in the network interface unit (NIU). A 160-bit network service access point (NSAP) address is also used.

The downstream transmission rate when using OOB is 3.088 Mbps. The downstream transmission rate for IB should be at multiples of 8kbps limited only by DVB-MS.

The upstream transmission rate is a mandatory 3.088 Mbps. A rate of 6.176 Mbps is also defined and other rates are allowed. Upstream framing consists of packets of 512 bits. The upstream slot rates are 12,000 slots per second at 6.176 Mbps and 6,000 slots per second at 3.088 Mbps.

Downstream IB transmission can use an EN 300 421 modem (PHY) and encodes the information in an MPEG-2 frame. Time markers are sent every 3 milliseconds.

For the purpose of 802.16.1, a framing structure based on the IB structure, rather than the OOB structure, is recommended.

[6] Reprinted from “The Stage has been set for High Speed Cable Modems and Set Top,” http://www.dvb.org/dvb_articles/dvb_rcc_scene.htm.

Upstream power control is define with a range of 28 dB, adjustable in 0.5 dB steps by the MAC, with a power accuracy of +/- 1.5 dB. For 802.16.1, it is suggested that a range of at least 60 dB be required to accommodate near-far, rain-fade, and PHY layer gain variations.

The upstream slot format contains a 53 byte payload, 4 byte unique word header, 6 byte Reed-Solomon Parity, and 1 byte guard band. The payload is an ATM cell per ITU-T Recommendation I.361.

The MAC contains functions for: initialization, provisioning, sign-on, calibration, connection management, setting access modes, link management (e.g. power control, timing, range calibration, TDMA allocation, and error management), and security (e.g. cryptographic primitives, key exchange, hashing, encryption, key derivation, data stream processing).

In addition to directly supporting ATM, the proposed MAC can be used to implement other mid-layer protocols including: IP, Ethernet MAC bridging, and PPP (see EN 301 199, para 6).

Reference Model

Provide a reference model including layering and mapping of functionality.

The general approach implements ATM on top of the MAC and a DVB PHY below the MAC.

The functionality of the MAC matches the IEEE 802 reference model with the logical link layer (LLC) above and the physical layer below. The LLC may be as defined by IEEE 802 are may be implemented with a simple ATM adaptation layer.

The MAC layer is between the logical link control (LLC) layer and the physical layer (PHY) layer (Figure 2). The MAC layer contains the functions that control the media (Figure 3). To specify an air interface, a minimum set of requirements is defined.

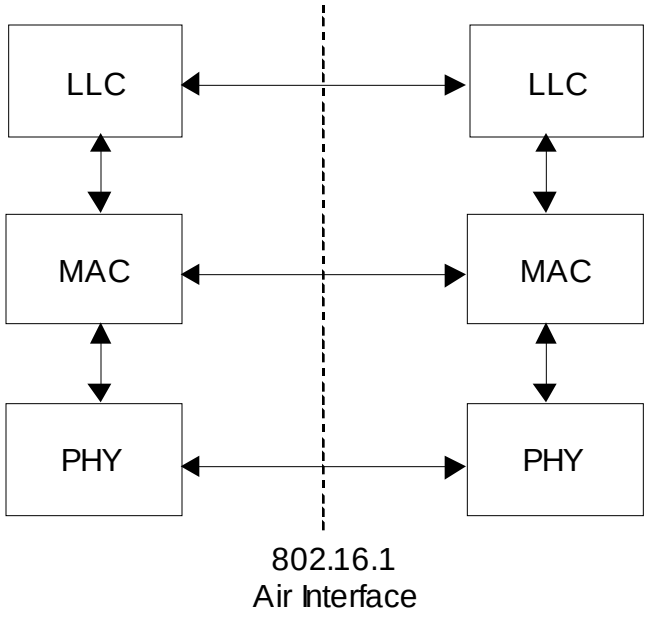

Figure 2, Simplified reference model for the proposed 802.16.1 MAC

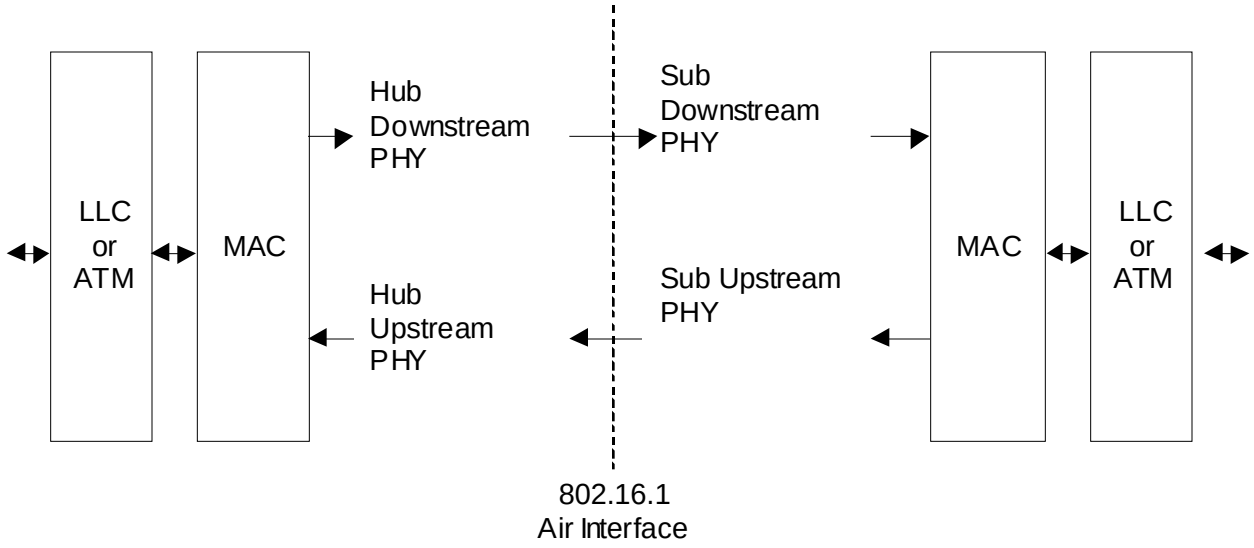

Figure 3, Proposed 802.16.1 MAC relative to other layers.

Transport of mid-level protocols, bandwidth granularity, frame structure, and overhead

Include method of over-the-air transport (IP, ATM, MPEG, etc.), granularity of bandwidth assignment, frame structure, and overhead characteristics.

Section 6 of EN 301 199 addresses transport of IP. The proposed MAC directly supports ATM and MPEG-2 transport.

Relationship to existing standards

Explain how the submitted MAC relates to existing standards, such as 802.14, DOCSIS, DVB, or others. If it is based on an existing standard, what differences occur due to BWA characteristics?

The proposed MAC is based on a DVB standard (EN 301 199) for broadband wireless access (BWA) applications. The DVB standard is also reproduced in ITU-T Recommendation J.112, Appendix A.

Benefits

Describe the benefits of the proposed MAC, including any unique features.

The proposed MAC is a complete set of requirements designed specifically for BWA systems.

The MAC is optimized for ATM, which supports the QoS requirements for both real-time and non-real time services.

The MAC supports TDMA in the upstream path and MPEG-2 transport streams downstream. The frame structure and burst formats are tailored for the fast packet approach of ATM cells. These features enable implementation within the radio of a multiplexing function with relatively small and deterministic delay. The implementation of a deterministic multiplexing function is a key capability of advanced P-MP radios that are used to provide services with guaranteed QoS requirements. The ability to perform muliplexing is key to allowing the air interface to provide a “pair-gain”, i.e. the radio system has many more possible subscriber (lines) than instantaneous subscribers at the network connection (trunks).

The proposed MAC is based on an existing standard.

Drawbacks

Describe any drawbacks of the proposed MAC.

The power control range of 28 dB needs to be increased to about 60 dB. For 28 GHz applications, an upstream automatic transmit power control dynamic range of about 30 dB for rain fade and 15 dB for near-far adjustment is necessary. Component tolerances and transmitter gain variation adds 15 dB more to the necessary power control range. The 802.16.1 version of the MAC should allow for at least 60 dB of power control range.

While the performance of the proposed MAC is relatively good, techniques exist for further improvement when implementing specifically for P-MP fixed wireless radios operating at 28 GHz.

Intellectual Property

Include a statement on intellectual property rights and how 802.16 may utilize the proposed MAC in a standard.

The ETSI intellectual property rights are contained in SR 000 314. See www.etsi.org/ipr.

Proposal Evaluation

The evaluation table is contained in Appendix A.

Conclusion

A MAC suitable for 802.16.1 has been presented. The proposed MAC is based on DVB/DAVIC as captured in ETSI EN 301 199. The approach allows efficient implementation of ATM on top of the MAC.

The author submits that a fast packet mid layer protocol, such as provided with ATM, is necessary to meet the service requirements for BWA systems that may carry telephony, video, and data services, simultaneously.

Appendix A, Proposal Evaluation Criteria

802.16 MAC Task Group: Session #4 Evaluation Table

#	Criterion	Discussion
1	*Meets system requirements*	*How well does the proposed MAC protocol meet the requirements described in the current version of the 802.16 System Requirements (Document IEEE 802.16s0-99/n)?* The proposed MAC is believed to meet all of the system requirements.
2	*MAC Delays*	*Is it possible to bound the delay of the proposed MAC protocol?* The analysis of delay for this MAC requires further study. However, the combined round-trip delay of the MAC and PHY is limited to 800 microseconds (EN 301 199, para 5.2.3.11). A downstream MAC message is restricted to no more than 120 bytes and is sent using AAL5 adaptation (EN 301 199, para 5.5.2.7). An upstream MAC message is a single 40-byte message also sent using AAL5 adaptation. The “fast packet” approach and features of ATM result in a relatively small and deterministic delay as opposed to the probabilistic delay inherent in IP based approaches.
3	*Payload and bandwidth efficiency*	*How well does the overhead due to the proposed MAC PDU headers allow for efficient user data transfer over the 802.16 air interface?* For downstream, the IB approach uses an MPEG2 transport stream and PID 0x1C which are designated for MAC messages (EN 301 199, para 5.3.2.1). The approach is sufficiently efficient that many video distribution and other applications throughout the world use the approach. For upstream, the MAC messages are sent as ATM cells on either contention or reservation access. (EN 301 199, para 5.5.2.4). *Is the proposed MAC protocol designed such that the MAC signaling is efficient in terms of not requiring excessive overhead?* The author submits that the MAC overhead is not excessive. *How well does the proposed MAC protocol provide the mechanisms for fair allocation and sharing of the bandwidth among users?* The MAC resource request message (EN 301 199, para) 5.5.5.2) has a 24-bit field labeled “Requested_Bandwidth.” that allows substantial range in allocating bandwidth. The TDMA approach enables sharing of bandwidth among users.

#	Criterion	Discussion
4	*Simplicity of implementation/cost*	*How well does the proposed MAC protocol allow for an implementation that is simple and generic enough that it is likely to be accepted by industry?* The approach is accepted as an ETSI standard and an ITU-T Recommendation. The approach has attained some level of acceptance, especially in Europe and South America.
5	*Scalability*	*Does the MAC protocol support a broad range of operational bandwidths and number of connections?* Yes, see discussion in criteria 3. The specific data rates defined in EN 301 199 are a good starting point, but unless the companion PHY requires specific data rates, an 802.16.1 version of the MAC could allow variable bandwidths and large numbers of connections.
6	*Service Support Flexibility*	*Does the MAC protocol support the services mentioned in the 802.16 System Requirements (Document IEEE 802.16s0-99/n) and is it open to the possible support of other services?* Yes, the ability to efficiently transport ATM implies that all services in the system requirements document can be supported.
7	*Robustness*	*Can the MAC protocol continue normal operation when presented with various unexpected events, e.g., corrupted MAC header, undefined MAC message (other protocol)?* *Is the MAC protocol able to recover from events such unexpected shut down or loss of link?* The MAC error handling procedures (EN 301 199, para 5.5.2.5) are under definition. Several time-out codes are defined (EN 301 199, para 5.5.3.2) that allow the MAC algorithms to exit from one of several exception conditions.
8	*Security*	*How well does the MAC protocol provide security mechanisms to meet the System Requirements?* Security (EN 301 199, para 5.7) is optional and has two separate subsystems. MAC messages are used during connection setup to authenticate and verify key-agreement between the hub and sub. Payload data streams are encrypted and decrypted on the fly. The security considerations in EN 301 199 are extensive, and appear to be well thought out.
9	*Physical Channel Configurability*	*Does the MAC protocol provide mechanisms to control the PHY parameters?* Yes, the MAC (EN 301 199, para 5.5.2.7) protocol contains an extensive set of messages for initializing, provisioning, and managing the PHY layer. Messages related to PHY management include transmission power adjustment, range timing

#	Criterion	Discussion
		calibration, and frequency assignment.
10	*Maturity*	*Does the proposed MAC protocol have data to demonstrate its ability to operate in an actual system that is representative of the BWA networks target for 802.16?* The DVB-RCCL (return channel for cable and LMDS) project is supported by a consortium of Alcatel, COCOM, DiviCom, Hughes Network Systems, Nokia, Sagem, Simac, Thomson Broadcast Systems, and Thomson Multimedia[7]. These and other manufacturers and users are investing time and resources in building and deploying DVB-RCCL products that include implementations of EN 301 199.
11	*Convergence with existing technologies*	*How simple is it to adapt the proposed MAC protocol to existing technologies?* The proposed MAC directly supports ATM mid-layer protocols, which in turn support broadband voice, video, and data services.
12	*Ability to work with physical layer variations, e.g., duplexing, constellation*	*How independent is the proposed MAC protocol of the PHY protocol?* The MAC appears to be capable of working with various PHY layers. The proposed MAC appears to be fairly well isolated from the PHY. The majority of the MAC is best suited for a software implementation and as such is semi-independent from the hardware oriented PHY. The MAC messages seem to assume a relatively simple PHY such as one that would use QPSK modulation but also include features sufficient for a TDMA upstream PHY.
13	*Mean access delay and variance*	*No submission required for Session #4; will address later*
14	*Sign-on process*	*No submission required for Session #4; will address later*
15	*Verifiability*	*No submission required for Session #4; will address later*
16	*Adequacy of management functions*	*No submission required for Session #4; may address later*

[7] "Leading Cable Manufacturers Join Forces to Support DVB-RCCL Standard for Cable Modems and Interactive Set-Top Boxes," http://www.ebu.ch/dvb/dvb_articles