Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Media Access Control Protocol Based on DOCSIS 1.1**
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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 upon DOCSIS 1.1 (Data Over Cable Service Interface Specifications). Modifications to this existing standard are included to support the requirements defined by the 802.16 Working Group for BWA networks.
Purpose	The author desires that the 802.16 working group incorporate all or part of the proposal into the 802.16.1 standard.
Notice	
Release	
IEEE Patent Policy	

Media Access Control Protocol Based on DOCSIS 1.1

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Introduction

This MAC proposal is based upon the DOCSIS specifications for cable modem systems. Specifically, the MAC portion of the RF Interface [SP-RFIv1.1-I02-990731] and the entire Baseline Privacy Plus [SP-BPI+-I02-990731] are proposed with modifications. The protocol is extended to support Broadband Wireless Access (BWA) networks as defined by the 802.16 Broadband Wireless Access System Requirements [IEEE 802.16s0-99/5].

Overview of Functions and Interfaces

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

The MAC layer is intended to support point-to-multi-point network communication in a fixed BWA system. Mechanisms are defined by which access to a centralized Base Station (BS) is given to one or more Subscriber Stations (SS) sharing a RF channel. Inherent in the protocol is the capability to use statistical multiplexing gain to achieve efficient use of the RF channels while providing flexible support for different traffic types across different stations and subscribers.

FDD is used to allocate downstream and upstream channels. Downstream transmissions are broadcast continuously to all SS in a MAC domain. Upstream transmissions are allocated based upon TDMA. Multiple upstream channels may be associated with a single downstream channel. Downstream channels interface to a transmission convergence sub-layer that carries MPEG-2 framed data. This framing directly carries the MAC-layer PDUs. Upstream transmissions are burst for the duration of one or more PDUs from a single SS. PDUs in either direction may be concatenated to provide additional efficiency by reducing MAC-layer overhead.

Four different MAC-layer PDUs are provided: variable-length, multiple ATM cell, multiple Synchronous Transfer Mode (STM) cell, and MAC management. The variable-length (802.3 and ethernet) and MAC management PDUs are encapsulated as 802.2 LLC frames.

Each upstream channel is divided into a series of mini-slots, which are the basic unit of granularity for upstream transmission. MAP messages are broadcast on the downstream channels that allocate mini-slots to each SS based upon the access mode. Each SS may access the upstream channel using five basic modes: ranging and initialization, maintenance, data transmission with contention, solicited grant (data transmission), and unsolicited grant (data transmission). Bandwidth requests may be piggybacked on upstream data transmissions to eliminate separate grant requests.

Stations are allocated one or more Service Flows, which are defined in terms of QoS parameters. The concept of Service Flows is central to the operation of the MAC protocol. In addition to providing the mechanism for upstream and downstream QoS management, they are integral to bandwidth allocation. Service Flows offer a unidirectional mapping between a SS and the BS. Each flow is represented by a unique identifier, to which bandwidth is allocated. An SS may have multiple service flows, each utilizing a different scheduling service and set of QoS parameters.

Service Flows may be provisioned statically. Alternatively, they may be dynamically created, modified, or deleted. This is accomplished through a series of MAC management messages. Dynamic modification of Service Flows can be initiated by the BS or SS. Authorization is always controlled at the BS. The BS may communicate with an external server to determine authorization policies. Service flows are used to support various traffic types, ranging from best effort to CBR emulation. This allows implementation of the bearer services outlined in the system requirements.

Ranging allows SS to calibrate timing, power, and frequency during initial station registration and at maintenance intervals. Timing calibration is critical to the operation of the upstream TDMA scheme. System time is maintained by the MAC layer and is distributed as a reference to a common source, allowing all stations to synchronize the upstream burst transmissions to mini-slot timing. This reference is distributed as a short MAC-layer management message at a regular interval, allowing the stations to maintain accurate time without extremely accurate clocking mechanisms.

The transmission properties and burst characteristics of the upstream channel(s) are broadcast at a regular interval on the downstream channel. Since various parameters of the channel can be adjusted dynamically, it is possible to perform automated spectrum management to help balance channel load and improve link performance. Note that although stations may be directed to change upstream channels, this is not intended to be a FDMA mechanism for granting upstream bandwidth.

An optional security sub-layer exists between the LLC (or equivalent) and MAC layers. Security consists of authentication using X.509 digital certificates and data privacy using DES encryption in CBC mode. Refresh of keying material occurs at regular intervals.

Protocol Operation

Upstream scheduling is accomplished using five native MAC layer access services. The Unsolicited Grant Service (UGS) provides a fixed-size upstream data transmission grant that occurs at a periodic interval. The key parameters for this service are the grant size, nominal grant interval, and the tolerated grant jitter. A real-time Polling Service (rtPS) provides upstream transmission request opportunities at fixed intervals. Note that this service provides the opportunity to request grants at periodic intervals while the UGS provides the grant opportunities without the need for requests. The Unsolicited Grant Service with Activity Detection (UGS-AD) provides the low-latency of the UGS service combined with the efficiency of the rtPS when not active. A non-real-time Polling Service (nrtPS) provides the same upstream scheduling mechanism as the rtPS without the low-latency polling. The Best Effort service (BE) provides contention and unicast request intervals in which stations contend for data grant transmission allocations.

QoS parameters are defined for the upstream services and are used to establish the characteristics of the upstream service flows. No restriction is placed on the number or combinations of the different service flow scheduling services for a given channel. The use of these parameters with the scheduling services is given in the following table.

Service Flow Parameter	Unsolicited Grant	Real-Time Polling	Unsolicited Grant w/Activity Detection	Non-Real-Time Polling	Best Effort
Traffic Priority	N/A	N/A	N/A	Optional	Optional
Maximum Sustained Traffic Rate	Optional	Optional	Optional	Optional	Optional
Maximum Traffic Burst Size	N/A	Optional	Optional	Optional	Optional
Minimum Reserved Traffic Rate	N/A	Optional	Optional	Optional	Optional
Unsolicited Grant Size	Mandatory	Optional	Mandatory	N/A	N/A

Service Flow Parameter	Unsolicited Grant	Real-Time Polling	Unsolicited Grant w/Activity Detection	Non-Real-Time Polling	Best Effort
Assumed Min Reserved Rate Packet Size	Optional	Optional	Optional	Optional	Optional
Maximum Concatenated Burst	N/A	Optional	Optional	Optional	Optional
Nominal Polling Interval	N/A	Mandatory	Optional	Optional	N/A
Tolerated Poll Jitter	N/A	Optional	Optional	N/A	N/A
Nominal Grant Interval	Mandatory	Optional	Mandatory	N/A	N/A
Tolerated Grant Interval	Optional	N/A	Optional	N/A	N/A
Grants per Interval	Mandatory	Optional	Mandatory	N/A	N/A

Downstream traffic is broadcast to all SS in a MAC domain. The BS effectively schedules bandwidth allocation in this direction without complex access mechanisms since contention resolution is not required. The DOCSIS protocol is extended to support downstream fragmentation. The operation of fragmentation in the downstream direction is similar to that of the upstream. It is implemented to allow the BS to meet jitter requirements when scheduling variable length ethernet/IEEE 802.3 frames on the same RF channel as constant rate traffic.

The protocol does not define the scheduling algorithms for the upstream scheduling services and the downstream broadcast transmissions, but does provide the native mechanisms necessary to support various higher-layer requirements.

Security

The intent of the security portion of the MAC is to provide subscribers with data privacy across the BWA and allow Service Providers to prevent unauthorized user's access to the BWA's RF MAC services. The proposed security protocol is based upon the DOCSIS Baseline Privacy Plus Specification without modification. The implementation of the security protocol is optional at individual SS. Further, an SS with the security capabilities is not required by the protocol to use those capabilities unless required by the provisioning process. Security is applied on an individual basis for each SS in a given RF channel.

MAC user payload data is encrypted using the Cipher Block Chaining (CBC) Mode of the US DES algorithm. MAC management messages are sent in the clear to facilitate registration, ranging, and the normal operation of the MAC layer.

A Baseline Privacy Key Management (BPKM) Protocol is defined to facilitate authorization and exchange of keying materials. Upon registration, the SS provides the BS with its RSA public key, X.509 digital certificate, and other identifying information. The BS verifies the identity of the SS and replies with an Authorization Key encrypted with the SS's public key. The SS then starts a Traffic Encryption Key (TEK) state machine that periodically requests TEK material from the BS. These periodic requests from the SS include its RSA public key and an Hashed Message Authentication Code (HMAC) keyed message (authenticating the request). The BS response includes a triple DES encrypted traffic key and an HMAC keyed message (authenticating the response). The Key Encryption Key (KEK) is derived from the Authorization Key.

Both TEK and Authorization Keys have a limited lifetime. Each SS is required to periodically reauthorize with the BS. It is the responsibility of the SS to obtain a fresh Authorization Key from the BS before expiration. Each TEK is provided by the BS to the SS with a given duration. The SS must also refresh the TEK before expiration.

Layer Management

The MAC and physical layers conceptually include management entities that provide layer-specific management interfaces to a layer-independent management entity. It is envisioned that these interfaces will be described in an abstract way at the MAC and PHY layers that do not dictate specific implementations or directly exposed interfaces. The layer-independent management entity in the equipment would be responsible for overall monitoring and control. It would expose relevant portions of the layer-specific management interface to system management entities through a standard interface. This would be a BWA-specific DOCSIS SNMP MIB that provides a large number of data and functions that map to the MAC and PHY layers.

Reference Model

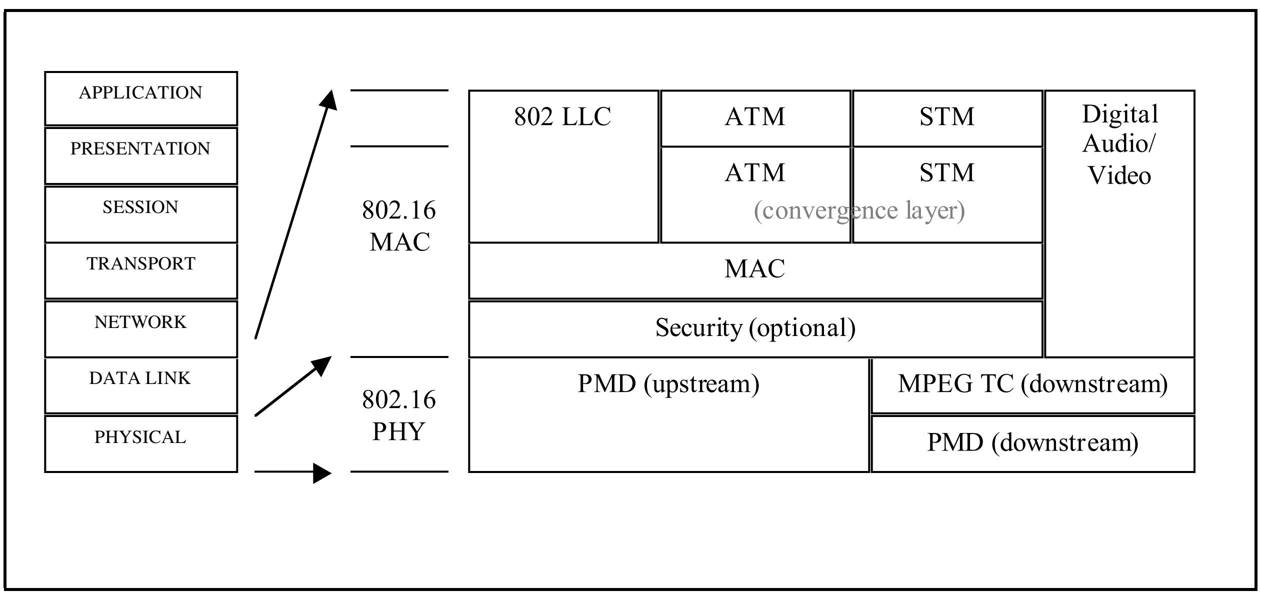
Provide a reference model including layering and mapping of functionality.

Figure 1 illustrates the proposed MAC layer and its relationship to the protocol stack. Access to the MAC layer is provided by a set of MAC sub-layer service primitives consistent with [ISO/IEC15802-1]. The interaction between the MAC layer and Security Sub-layer is limited to two security-specific MAC messages and the encrypted payloads.

The MAC layer controls many of the PHY layer characteristics. For example, the MAC layer control of the upstream channel transmissions and burst profiles allows the network to be provisioned for optimal performance. The MAC layer is designed with independence in areas where the PHY layer scales in transmission rates and modulation types.

A Service Access Point (SAP) is provided at the MAC layer to allow mapping of ATM and STM cells into the native MAC format. These convergence sublayers provide a mapping of the QoS requirements of these higher layers into the native MAC format and QoS mechanisms.

Figure 1. Protocol Stack



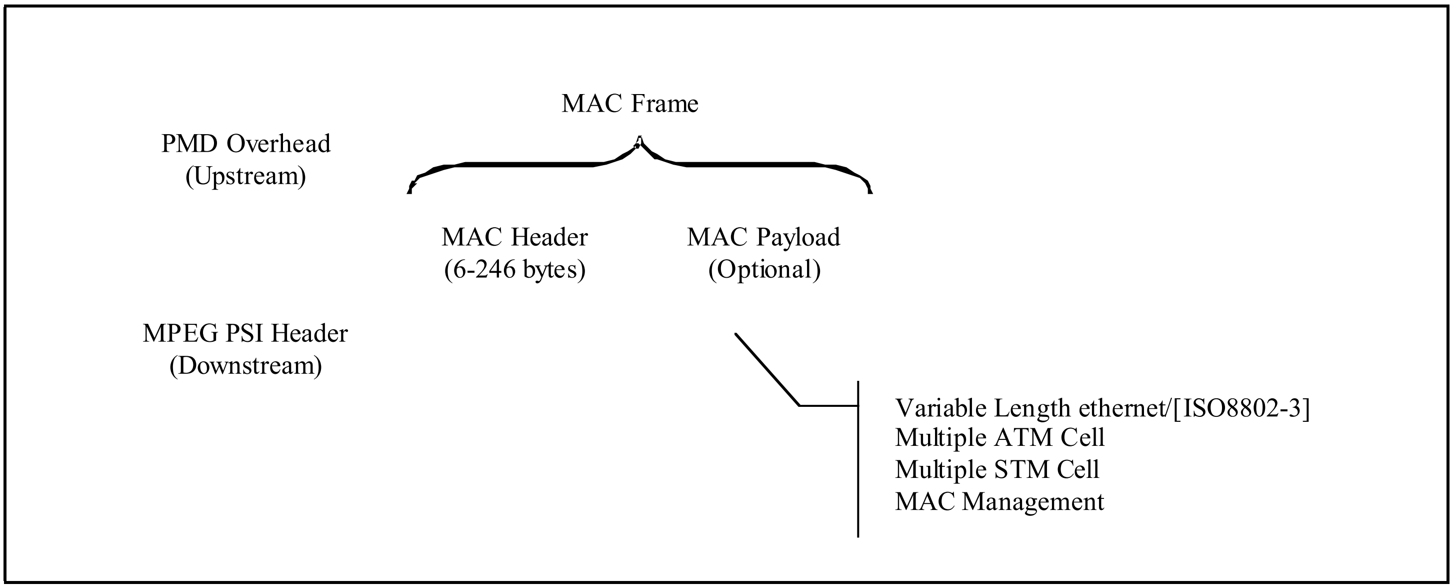
Transport of mid-level protocols, bandwidth granularity, frame structure, and overhead

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

Downstream transmissions are framed in 188-octet MPEG [ITU-T H.222.0] packets, each consisting of a 4-byte header followed by 184 bytes of payload. A well-defined header uniquely identifies packets that belong to the BWA MAC. MAC frames are adapted into the MPEG packets. The upstream uses a burst format in which the MAC frame is prefixed with PMD overhead (including guard times). These general frame structures are illustrated in Figure 2. This MAC-specific frame structure is consistent in both the upstream and downstream directions. The MAC frame consists of a varying length header followed by an optional payload. The MAC header varies in size based upon the MAC message type and the use of extended headers. Extended headers convey information such as keying material for security. The payload varies as a function of the payload content. For example, the payload contains 15 to 1522 bytes when transporting an Ethernet/[ISO8802-3]-type packet. Alternatively, the payload may contain multiple ATM cells, each 53 bytes in length.

Each MAC Header is verified by a 16-bit Header Check Sequence (HCS) which covers the entire MAC Header including any extended components. The HCS is intended to ensure the integrity of the MAC Header in a collision/contention environment.

Figure 2. Generic MAC Frame Format

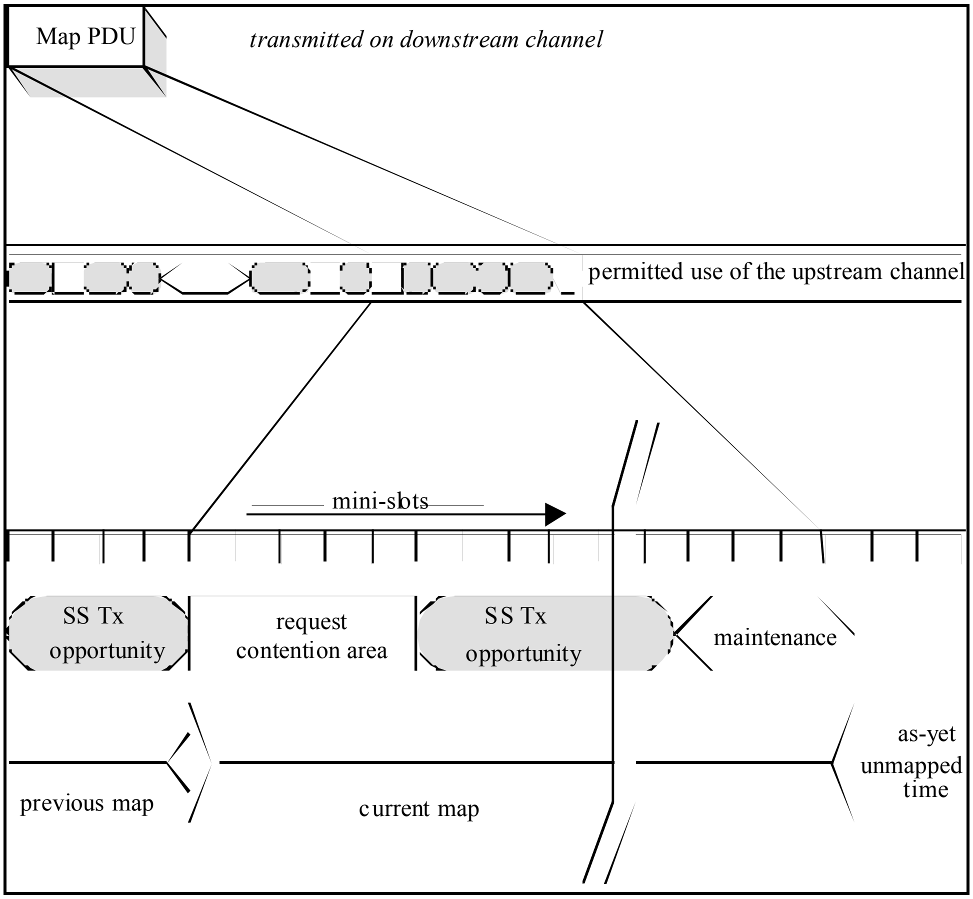


MAC Management messages are encapsulated in an LLC unnumbered information frame per [ISO8802-2], which are in turn, encapsulated within the BWA MAC framing. Management messages can be classified into general categories of ranging, upstream channel description, upstream bandwidth allocation and control, registration, key management, and dynamic service. Ranging messages provide the means to calibrate system time, power, and frequency for optimal PHY and MAC layer performance. Upstream channel description messages define the transmission characteristics of a channel and the burst characteristics of the different intervals within a transmission. Upstream bandwidth allocation and control provides the means to grant mini-slot allocation to either unicast or multicast addressed stations. SS use these allocations to contend for upstream access grants, send data, or attempt entry into the network. Registration provides the means to perform basic admission control of the station into the network and to provide initial addressing and QoS assignments. Key management messages provide a mechanism by which the refresh of security keying material occurs. This is the only interface of the security layer to the MAC layer other than the data payloads that are encrypted/decrypted. Finally, dynamic service messages provide a mechanism to dynamically create and remove service flows. This is an essential requirement for supporting VoIP applications and ATM virtual connections.

Bandwidth Granularity and Allocation

Mini-slots are the basic unit of granularity for upstream transmission. This submission proposes modification of DOCSIS to support mini-slot independence from the symbol rate. This allows the mini-slot length to be provisioned to a number of bytes that is efficient relative to expected SDU length and the bandwidth allocation process. Typical mini-slot sizes are 8, 16, and 32 bytes. Mini-slots map a continuous time line of upstream transmissions for all stations in a MAC domain. Figure 3 illustrates this time line.

Figure 3. Mini-Slot Allocation Example (BE)

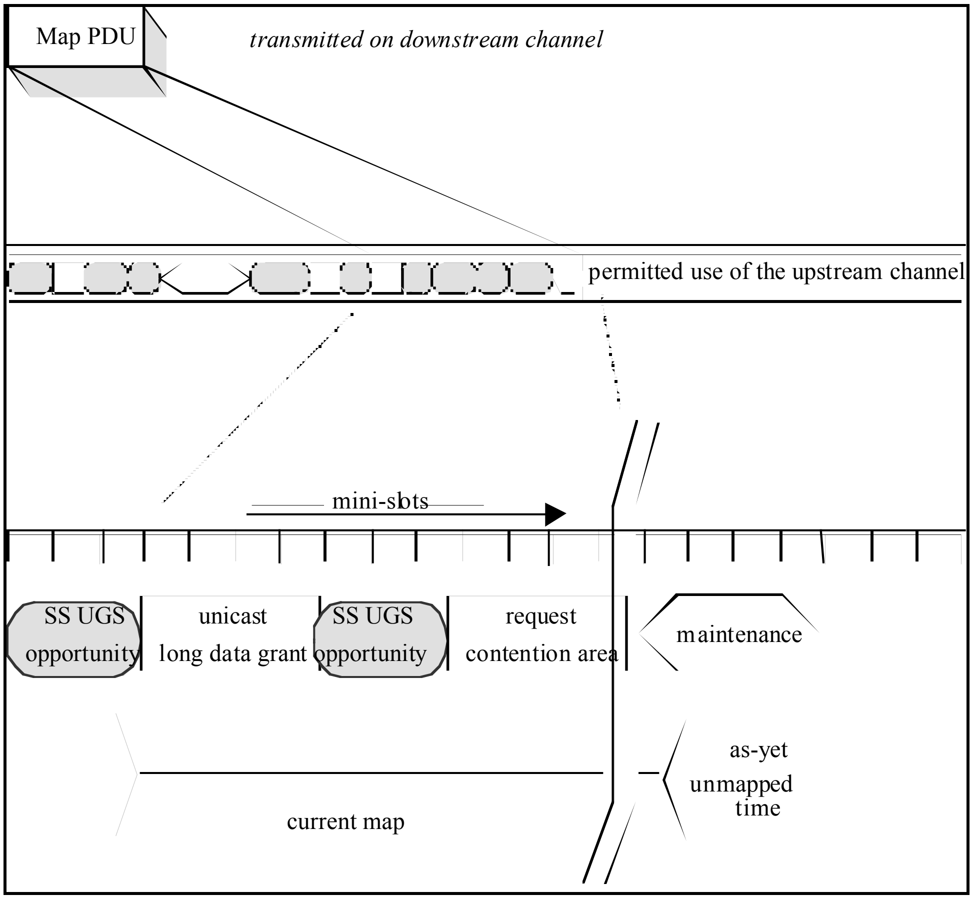


Upstream transmissions are allocated as one or more mini-slots. Each allocation is explicitly defined as one of five specific modes in a MAP message. Contention intervals are used for ranging (maintenance and initial), Best Effort service, and polling services. Contention intervals are an opportunity for an SS to request a grant from the BS for upstream transmission. The interval may be broadcast to all SS or unicast to a single SS. Contention resolution is accomplished using a truncated binary exponential back-off algorithm. The initial and maximum window sizes are controlled by the BS. Contention requests for data transmission grants are acknowledged by the BS in unicast grant opportunities in later MAPs.

Requests are made for short and long data grants. Each grant type is defined with different burst parameters, allowing the system to be provisioned with different FEC based upon the grant size. For example, short UDP packets could be provisioned with less FEC than long grants for more efficient bandwidth utilization.

The UGS service bypasses the request interval by granting upstream transmission intervals at a provisioned rate. Using this service, an SS is given a constant upstream bandwidth allocation at a constant rate. Figure 4 illustrates the use of the USG service to allocate a unicast grant opportunity of three mini-slots to an SS at a fixed rate. Interspersed with those grants are a unicast long data grant (in response to a prior request) and a request contention interval for best effort services. The ability of the MAC layer to operate independently of the mini-slot payload allows upstream channels to support multiple transport types. Different data grants can carry any of the PDU packet types: MAC Management, ATM PDU, Ethernet/802.3 PDU, or STM PDU. A form of statistical multiplexing gain is achieved by allowing convergence of the different traffic types on the same channel.

Figure 4. Mini-Slot Allocation Example (UGS)



The rtPS and nrtPS operate in the same manner as the UGS except they allocate request contention intervals instead of data grants. The polling services provide unicast request intervals on a periodic basis. An SS uses these opportunities to request bandwidth via a data grant. In the real-time mode the SS is polled at a specified interval with a bound on the Tolerated Poll Jitter. In the non-real-time mode, the BS offers request intervals using a vendor-defined allocation algorithm – no Poll Interval or corresponding jitter tolerance is specified.

DOCSIS provides the ability to fragment PDUs in the upstream[1]. This allows the BS to split longer Ethernet/802.3 frames into multiple data grants. Fragmentation is used by the BS to ensure the UGS grant size and jitter tolerance QoS commitments can be made in the presence of varying length BE traffic. The longer, variable length traffic is shaped to meet the available remaining grant intervals after the allocation of the UGS and PS traffic.

Support for Higher Layer Protocols

The initial DOCSIS 1.0 interface specifications were designed to carry Best Effort IP traffic. The building blocks for supporting higher layer protocols and associated QoS requirements were in place via the mini-slot mechanism but were not developed. DOCSIS 1.1 defines these QoS and service flow mechanisms. The proposed MAC further extends the specification to include support for transport of ATM and STM cells.

Overhead

The MAC layer overhead is introduced into the transmission stream from three different aspects of the protocol. Each MAC message contains a MAC Header, which is a minimum of six bytes in length. Extended MAC Headers are used to support various aspects of the protocol operation. These headers vary in length based upon the amount of specialized payload management that occurs. For example, an encrypted payload requires the overhead of four additional bytes in the MAC Header.

[1] This submittal proposes using the same capability in the downstream.

A second source of overhead results from non-optimal use of mini-slot allocations. This occurs when the MAC frame does not exactly fit into an integral number of mini-slot grants. The mini-slot granularity is kept to a small number of bytes relative to the MAC frame size to minimize bandwidth inefficiency.

MAC Management messages also introduce overhead into the protocol. Of these, the largest use of bandwidth is for the transmission of MAP messages. Characterization of the amount of bandwidth used for MAP message transmission is difficult since this is a function of the MAP size that is a result of the vendor implemented scheduling algorithm. In the present DOCSIS protocol, MAP messages are typically generated 200 times per second and can require anywhere between 48 and 600 bytes per transmission[2]. This is a very small portion of the available downstream bandwidth.

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?

This proposal is based upon the DOCSIS 1.1 specifications for the RF interface and Baseline Privacy Plus.

Extensions have been made to these specifications to support BWA systems. The transmission rates are significantly increased in both the downstream and upstream channels. The downstream channel now supports QPSK modulation. Coding techniques are modified to support BWA RF links carrying ATM and STM traffic. All of these PHY layer modifications are supported in the MAC layer.

System timing is modified to allow consistent mini-slot granularity when scaling symbol rates. This provides increased independence of the MAC layer from PHY layer. Consistent mini-slot granularity removes one complexity from upstream scheduling algorithms.

Ranging messages are improved to support timing and synchronization at the higher transmission rates. Power control and calibration is optimized to better support the unique environmental characteristics of the BWA RF links. Frequency adjustment ranging is expanded for easier acquisition of the upstream bursts.

Existing definition for the transport of ATM cells is extended to map ATM QoS requirements into the DOCSIS 1.1 QoS definitions. Additional MAC-layer support for the transport of PDH/SDH traffic is implemented using emulated CBR via STM cells. This mechanism is implemented to allow efficient transport of PDH/SDH traffic without the overhead of ATM adaptation.

Benefits

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

The submission meets the requirements set forth in [IEEE 802.16s0-99/5].

The proposed MAC is based on existing DOCSIS specifications that have been proven in modeling, certification, and deployment. Hardware and software solutions for the DOCSIS 1.1 specifications exist from multiple sources. The proposed extensions to the DOCSIS MAC are straightforward and scale well. Components of the proposed MAC layer are similar to the proposed 802.14 MAC layer.

The mechanisms to support scheduling algorithms are provided by the protocol. However, the actual implementation of these algorithms is left up to the vendor to allow the best possible solutions to be developed.

Drawbacks

Describe any drawbacks of the proposed MAC.

[2] These numbers are based upon general modeling experience with the protocol and are not dependent upon a given vendor's implementation. Larger map message sizes are related to the number of different service flows that must be granted access per map message.

The DOCSIS protocols are designed to operate in the harsh conditions of an HFC plant. This required the ability to be able to provision a large number of parameters related to the upstream transmissions and burst characteristics. Further investigation is required to determine which of these capabilities need to be provisioned and which can be fixed by the specification.

Intellectual Property

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

General Instruments, Bay Networks (Nortel), 3Com, and Broadcom have claimed Intellectual Property Rights (IPR) in the DOCSIS Licensing Agreement published by CableLabs. The extent of this IPR has not been made public.

Implementation of the Baseline Privacy Plus specification requires the use of RSA (object or source) code. Licensing of this software artifact will be required to implement the optional security components of the protocol.

References

[IEEE 802.16s0-99/5] Preliminary Draft Working Document for 802.16 Broadband Wireless Access System Requirements, IEEE 802.16 BWA Working Group.

[ISO8802-2] ISO/IEC 8802-2: 1994 (IEEE Std. 802.2: 1994) – Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific Requirements – Part 2: Logical Link Control.

[ISO8802-3] ISO/IEC 8802-3: 1996 (IEEE Std. 802.3: 1996) – Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical sublayer specifications.

[ITU-T H.222.0] ITU-T Recommendation H.222.0 (1995) | ISO/IEC 13818-1:1996, Information Technology – generic coding of moving pictures and associated audio information systems.

[SP-RFIv1.1-I02-990731] Data-over-cable Service Interface Specifications, Radio Frequency Interface Specifications, Cable Labs.

[SP-BPI+-I02-990731] Data-over-cable Service Interface Specifications, Baseline Privacy Plus Interface Specification, Cable Labs.

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 UGS service and associated QoS parameters provide the means to schedule a fixed bound on the delay introduced by the MAC. For example, these bounds are controlled to allow CBR emulation through ATM adaptation and direct STM cell transfer.
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?* The MAC headers vary in length to allow the minimum size header to be used based up the type of payload and its associated characteristics. Mechanisms such as MAC frame concatenation and piggyback requests reduce overhead introduced by the MAC layer. *Is the proposed MAC protocol designed such that the MAC signaling is efficient in terms of not requiring excessive overhead?* The MAC layer was originally designed for operation in a cable modem network in which bandwidth was at a premium. The protocol design was optimized for efficient use of bandwidth by the MAC layer, especially for upstream traffic. These efficiencies are carried forward into the proposed MAC. *How well does the proposed MAC protocol provide the mechanisms for fair allocation and sharing of the bandwidth among users?* Bandwidth is allocated to service flows on demand based upon the QoS requirements of those flows. This mechanism not only allows the sharing of bandwidth but also provides statistical multiplexing gain by “over-subscription” of user bandwidth.
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 propose MAC is based on a widely accepted standard that is currently being used to develop, certify, and field networks from multiple vendors. The proposed extensions fit well within the existing protocol and are believed to be simple and generic enough to be accepted by the Vendor community. Cost for cable modem implementation has been proven to be low enough to support equipment deployment down to the residential level. This is a strong indicator of the low cost for the BWA modem components.

#	Criterion	Discussion
5	*Scalability*	*Does the MAC protocol support a broad range of operational bandwidths and number of connections?* A given MAC domain can support up to 4096 unique Service Flows. Each Service Flow can be thought of as a virtual connection with its own independent QoS requirements. Individual Service Flows can be allocated a broad range of bandwidths based upon higher-layer bearer service requirements
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?* The different bearer services defined by the system requirements (IP, ATM, PDH/SDH) are supported by the protocol. The native MAC layer services are not tied to a specific service type, allowing possible support of other services than those already defined.
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)?* The protocol validates the MAC header with a Header Check Sequence and length encoding. Methods are defined for handling unexpected events such as invalid MAC Header field codes, etc. *Is the MAC protocol able to recover from events such unexpected shut down or loss of link?* The loss of an SS on a link does not prevent the MAC layer from operating normally. Loss of an entire RF link does not affect the operation of the MAC on any other operation channels. An SS will either automatically re-synchronize or re-register if an RF link is lost (depending upon the length of the outage).
8	*Security*	*How well does the MAC protocol provide security mechanisms to meet the System Requirements?* The proposed MAC is believed to meet all of the security requirements.
9	*Physical Channel Configurability*	*Does the MAC protocol provide mechanisms to control the PHY parameters?* The MAC protocol provides control over transmission characteristics of a RF channel and the individual upstream burst

#	Criterion	Discussion
		characteristics.
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?* Operational data can be collected using implementation of the DOCSIS standards in both laboratory and field environments.[3] The DOCSIS MAC is currently used in HFC plants that present a RF environment with many interference and noise sources. OPNET models are available for both DOCSIS 1.0 and 1.1. The OPNET models are publicly available and can be used as a basis for modeling the extensions proposed by this submission.
11	*Convergence with existing technologies*	*How simple is it to adapt the proposed MAC protocol to existing technologies?* The proposed MAC is based upon existing standards that use a variety of existing technologies. Adaptation to the extended requirements of the proposed modifications builds upon these existing technologies.
12	*Ability to work with physical layer variations, e.g., duplexing, constellation*	*How independent is the proposed MAC protocol of the PHY protocol?* The proposed MAC is designed to be independent of the physica layer characteristics (symbol rate, modulation type, FEC encoding, interleaving, etc.). Specifically, the mini-slot sizing technique is a key protocol feature, allowing the PHY layer to scale transmission rates without affecting the general operation o the MAC layer.
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*

[3] The use of deployed DOCSIS networks for data collection may be problematic because of Service Provider intellectual property concerns.