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| Project | **IEEE 802.16 Broadband Wireless Access Working Group** | |
| Title | **DOCSIS based MAC layer proposal for BWA** | |
| Date Submitted | **1999-10-21** | |
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| Re: | This contribution is submitted in response to call for contributions from the IEEE 802.16 chair on Sept.22nd, 1999 for submission of MAC proposals for BWA | |
| Abstract | The MAC proposal based on DOCSIS (Data over Cable Systems Interface Specifications) is submitted for consideration by the group to be accepted as MAC standards for BWA. | |
| Purpose | This proposal should be accepted as MAC standard for BWA | |
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# MAC proposal based on DOCSIS

## Introduction

This contribution proposes that MAC standards be developed for BWA based on DOCSIS standards as specified in ITU-R draft Recommendation ITU-T J.116 (Annex B) [1] and ITU-R draft Recommendation ITU-R F.BWA [2]. These draft Recommendations use ITU-T Recommendations J.112 [3] and J.83 [4] for cable modems as the **basis** for **wireless** access systems in order to achieve **economies of scale**. The technical parameters have been adapted to the wireless environment rather than for a cable environment in order to support bidirectional data over broadband **wireless** access systems for interactive services. The specifications in these ITU standards are based on DOCSIS 1.0. The additional features of DOCSIS 1.1 as proposed by Phasecom [5] at the Sept. '99 meeting can be used to build upon the specification proposed here to allow additional features for provisioning of multimedia services.

**Media Access Control Specification**

### Overview

This section describes version 1.0 of the BWA MAC protocol. Some of the MAC protocol highlights include:

- Bandwidth allocation controlled by BWA BTS Modem.
- A stream of mini-slots in the upstream.
- Dynamic mix of contention- and reservation-based upstream transmit opportunities.
- Bandwidth efficiency through support of variable-length packets.
- Extensions provided for future support of ATM or other Data PDU.
- Class of service support.
- Extensions provided for security as well as virtual LANs at the Data Link layer.
- Support for a wide range of data rates.

### Definitions

**MAC-Sublayer Domain**
A MAC-sublayer domain is a collection of upstream and downstream channels for which a single MAC Allocation and Management protocol operates. Its attachments include one BWA BTS Modem and some number of BWA CPE Modems. The BWA BTS Modem MUST service all of the upstream and downstream channels; each BWA CPE Modem MAY access one or more upstream and downstream channels.

**MAC Service Access Point**
A MAC Service Access Point (MSAP) is an attachment to a MAC-sublayer domain.

**Service ID**
The concept of Service IDs is central to the operation of the MAC protocol. Service IDs provide both device identification and class-of-service management. In particular, they are integral to upstream bandwidth allocation. A Service ID defines a particular mapping between a BWA CPE Modem and the BWA BTS Modem. This mapping is the basis on which bandwidth is allocated to the BWA CPE Modem by the BWA BTS

Modem and by which class of service is implemented. Within a MAC-sublayer domain, all Service IDs MUST be unique. The Service ID is unique within a single MAC-sublayer domain. The length of the Service ID is 14 bits (although the Service ID is sometimes carried in a 16-bit field).

**Upstream Intervals, Mini-Slots and 6.25-Microsecond Increments**
The upstream transmission time-line is divided into intervals by the upstream bandwidth allocation mechanism. Each interval is an integral number of mini-slots. A "mini-slot" is the unit of granularity for upstream transmission opportunities. There is no implication that any PDU can actually be transmitted in a single mini-slot. Each interval is labelled with a usage code which defines both the type of traffic that can be transmitted during that interval and the physical-layer modulation encoding. A mini-slot is an integer multiple of 6.25 μsec increments.

**Frame**
A frame is a unit of data exchanged between two (or more) entities at the Data Link Layer. A MAC frame consists of a MAC Header (beginning with a Frame Control byte), and may incorporate ATM cells or a variable-length data PDU. The variable-length PDU includes a pair of 48-bit addresses, data, and a CRC sum. In special cases, the MAC Header may encapsulate multiple MAC frames.

### Future Use

A number of fields are defined as being "for future use" in the various MAC frames. These fields MUST NOT be interpreted or used in any manner.

## *MAC Frame Formats*

### Generic MAC Frame Format

A MAC frame is the basic unit of transfer between MAC sublayers at the BWA BTS Modem and the BWA CPE modem. The same basic structure is used in both the upstream and downstream directions. MAC frames are variable in length. The term "frame" is used in this context to indicate a unit of information that is passed between MAC sublayer peers. This is not to be confused with the term "framing" that indicates some fixed timing relationship. There are three distinct regions to consider, as shown in Figure 1. Preceding the MAC frame is either PMD sublayer overhead (upstream) or an MPEG transmission convergence header (downstream). The first part of the MAC frame is the MAC Header. The MAC Header uniquely identifies the contents of the MAC frame. Following the header is the optional Data PDU region. The format of the Data PDU and whether it is even present is described in the MAC Header.

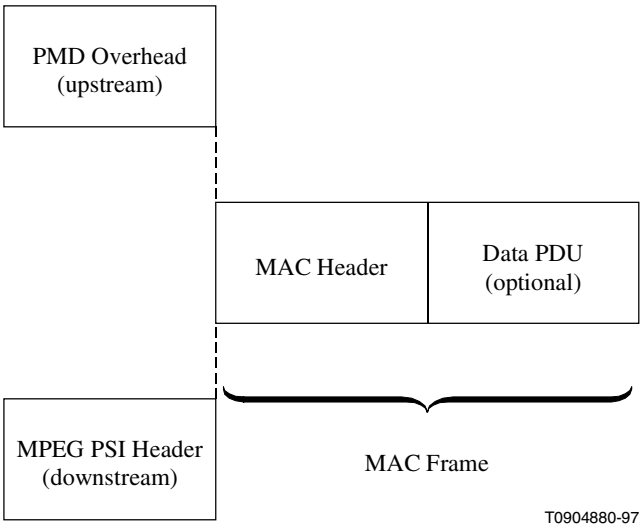


Figure 1
**Generic MAC Frame Format**

**PMD Overhead**

**Upstream**

In the upstream direction, the PHY layer indicates the start of the MAC frame to the MAC sublayer. From the MAC sublayer's perspective, it only needs to know the total amount of overhead so it can account for it in the Bandwidth Allocation process. The FEC overhead is spread throughout the MAC frame and is assumed to be transparent to the MAC data stream. The MAC sublayer does need to be able to account for the overhead when doing Bandwidth Allocation.
The transport of MAC frames by the PMD sublayer for upstream channels is shown in Figure 2.

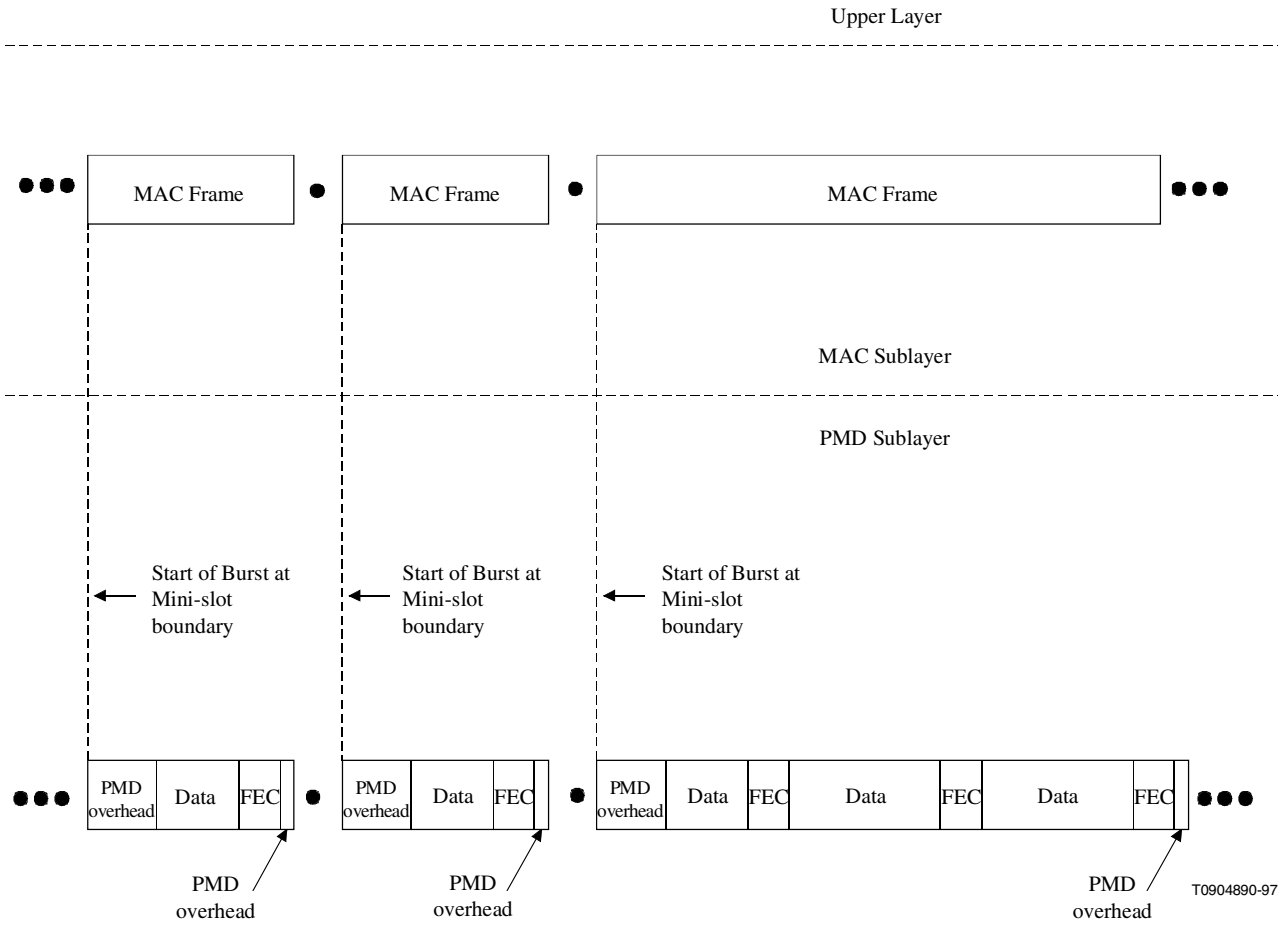


FIGURE 2

**Upstream MAC/PMD Convergence**

## Downstream

The layering of MAC frames over MPEG in the **downstream** channel is described below:

In order to improve demodulation robustness, facilitate common receiving hardware for both video and data, and provide an opportunity for the possible future multiplexing of video and data over the PMD sublayer bitstream, a sublayer is interposed between the downstream PMD sublayer and the Data-Over-BWA MAC sublayer. The downstream bitstream is defined as a continuous series of 188-byte MPEG [8] packets. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the Data-Over-BWA MAC. Other values of the header may indicate other payloads. The mixture of MAC payloads and those of other services is optional and is controlled by the BWA BTS Modem. Figure 3 illustrates the interleaving of Data-Over-BWA (DOC) MAC bytes with other digital information (digital video in the example shown).

| | |
|---|---|
| header=DOC | DOC MAC payload |
| header=video | digital video payload |
| header=video | digital video payload |
| header=DOC | DOC MAC payload |
| header=video | digital video payload |
| header=DOC | DOC MAC payload |
| header=video | digital video payload |
| header=video | digital video payload |
| header=video | digital video payload |

FIGURE 3

**Example of Interleaving MPEG Packets in Downstream**

## *MAC Management Messages*

MAC management messages MUST be encapsulated in an LLC unnumbered information frame per [ISO8802-2], which in turn is encapsulated within the BWA network MAC framing. Some of the MAC management message type examples include Sync, Upstream Channel Descriptor (UCD), MAP, Ranging Request, Ranging Response, Registration Request and Registration Response

## *Upstream Bandwidth Allocation*

The upstream channel is modelled as a stream of mini-slots. The BWA BTS Modem MUST generate the time reference for identifying these slots. It MUST also control access to these slots by the BWA CPE modems. For example, it MAY grant some number of contiguous slots to a BWA CPE Modem for it to transmit a data PDU. The BWA CPE Modem MUST time its transmission so that the BWA BTS Modem receives it in the time reference specified. This section describes the elements of protocol used in requesting, granting, and using upstream bandwidth. The basic mechanism for assigning bandwidth management is the allocation map. Please refer to Figure 5.

The allocation map is a MAC Management message transmitted by the BWA BTS Modem on the downstream channel which describes, for some interval, the uses to which the upstream mini-slots MUST be put. A given map MAY describe some slots as grants for particular stations to transmit data in, other slots as available for contention transmission, and other slots as an opportunity for new stations to join the link.

Many different scheduling algorithms MAY be implemented in the BWA BTS Modem by different vendors; this specification does not mandate a particular algorithm. Instead, it describes the protocol elements by which bandwidth is requested and granted.

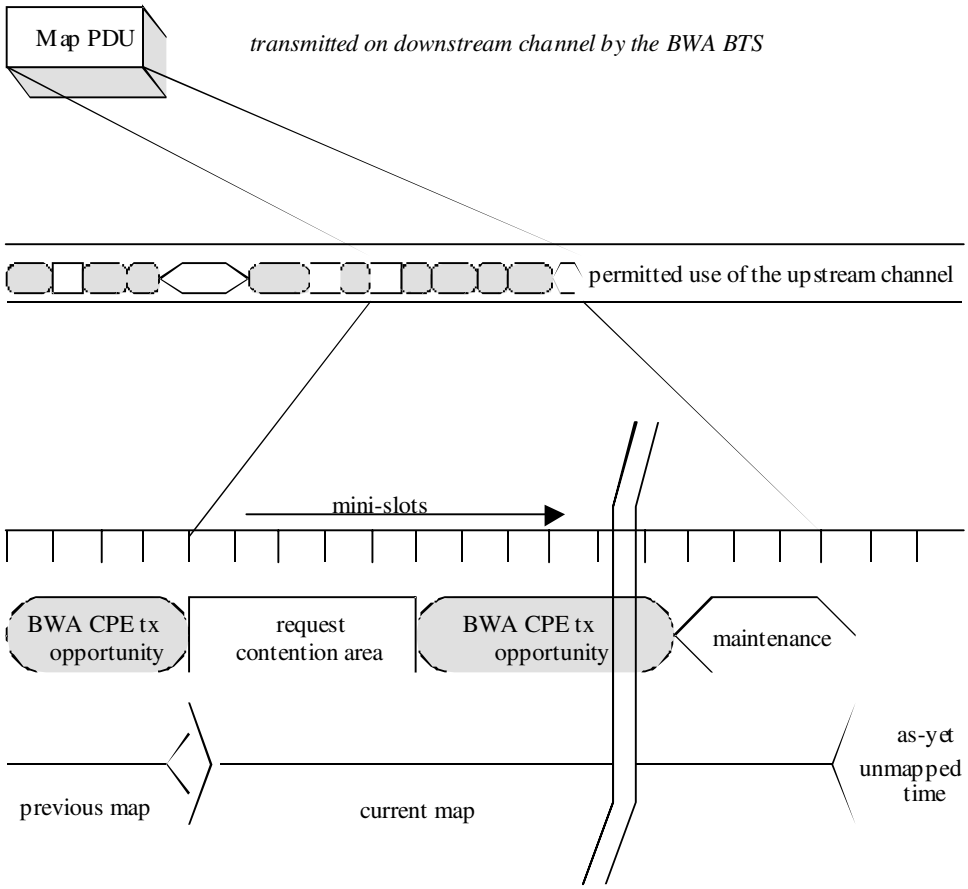


FIGURE 5

**Allocation Map**

The bandwidth allocation MUST include the following basic elements:

- Each BWA CPE Modem has one or more short (14-bit) service identifiers as well as a 48-bit address.
- Upstream bandwidth is divided into a stream of mini-slots. Each mini-slot is numbered relative to a master reference maintained by the BWA BTS Modem. The clocking information is distributed to the BWA CPE Modems by means of SYNC packets.
- BWA CPE Modems MAY issue requests to the BWA BTS Modem for upstream bandwidth.

The BWA BTS Modem MUST transmit allocation map PDUs on the downstream channel defining the allowed usage of each mini-slot.

### - Map Transmission and Timing

The allocation map MUST be transmitted in time to propagate across the physical cable and be received and handled by the receiving BWA CPE Modems . As such, it MAY be transmitted considerably earlier than its effective time. The components of the delay are:

- Worst-case round-trip propagation delay - may be network-specific, but on the order of hundreds of microseconds.
- Queuing delays within the BWA BTS Modem - implementation-specific.
- Processing delays within the BWA CPE Modems - MUST allow a minimum processing time by each BWA CPE Modem
- PMD-layer FEC interleaving.

Within these constraints, vendors MAY wish to minimize this delay so as to minimize latency of access to the upstream channel. The number of mini-slots described MAY vary from map to map.

### - Contention Resolution

The BWA BTS Modem controls assignments on the upstream channel through the MAP and determines which mini-slots are subject to collisions. The BWA BTS Modem MAY allow collisions on either Requests or Data PDUs. The mandatory method of contention resolution which MUST be supported is based on a truncated binary exponential back-off, with the initial back-off window and the maximum back-off window controlled by the BWA BTS Modem. The values are specified as part of the Bandwidth Allocation Map (MAP) MAC message and represent a power-of-two value. For example, a value of 4 indicates a window between 0 and 15; a value of 10 indicates a window between 0 and 1023. When a BWA CPE Modem has information to send and wants to enter the contention resolution process, it sets its internal back-off window equal to the initial back-off window defined in the MAP currently in effect. The BWA CPE Modem MUST randomly select a number within its back-off window. This random value indicates the number of contention transmit opportunities which the BWA CPE Modem MUST defer before transmitting. A BWA CPE Modem MUST only consider contention transmit opportunities for which this transmission would have been eligible.

### - BWA CPE Modem Behaviour

The following rules govern the response a BWA CPE Modem may make when processing maps:

1) A BWA CPE Modem MUST first use any Grants assigned to it. Next, the BWA CPE Modem MUST use any unicast REQ for it. Finally, the BWA CPE Modem MUST use then next available broadcast/multicast REQ or REQ/Data IEs for which it is eligible.

2) Only one Request may be outstanding at a time for a particular Service ID.

3) If a BWA CPE Modem has a Request pending, it MUST NOT use intervening contention intervals for that Service ID.

### - Support for Multiple Channels

Vendors MAY choose to offer various combinations of upstream and downstream channels within one MAC service access point. The upstream bandwidth allocation protocol allows for multiple upstream channels to be managed via one or many downstream channels.

### - Classes of Service

This specification does not provide explicit classes of service, but provides the means for vendors to provide a variety of types of service.
This section illustrates how the available mechanisms can be used to provide support for the service classes defined in [RFC-1633] "Integrated Services in the Internet Architecture: An Overview".
[RFC-1633] divides applications into elastic applications which will always wait for data to arrive and inelastic applications in which the data must arrive within a certain time to be useful.
Within the inelastic category further sub divisions can be defined:

- delay-intolerant - the data must arrive within a perfectly reliable upper bound on delay;
- delay-tolerant - the data must arrive within a fairly reliable but not perfectly reliable delay bound.

Within the elastic category the following application types can be distinguished:

- interactive burst;
- interactive bulk.

The service model should be able to support both types of inelastic application and to allow for lower delays for interactive elastic applications than for bulk elastic applications.

**- Resource-Sharing**
In order to support multiple end systems sharing the same upstream and downstream links, it is necessary to provide resource-sharing mechanisms for the link bandwidth

## *Timing and Synchronization*

One of the major challenges in designing a MAC protocol for a cable network is compensating for the large delays involved. These delays are an order of magnitude larger than the transmission burst time in the upstream. To compensate for these delays, the BWA CPE modem MUST be able to time its transmissions precisely to arrive at the BWA BTS Modem at the start of the assigned mini-slot.
To accomplish this, two pieces of information are needed by each BWA CPE modem:

- a global timing reference sent downstream from the BWA BTS Modem to all BWA CPE modems;
- a timing offset, calculated during a ranging process, for each BWA CPE modem.

## *Data Link Encryption Support*

The procedures to support data link encryption are defined in [6,7]. The interaction between the MAC layer and the security system is limited to MAC messages and Framing.

## REFERENCES

[1] ITU-T Draft Recommedation J.116: Interaction channel for Local Multipoint Distribution Services, Sept. 1999

[2] Draft Recommendation ITU-R F.BWA: Radio Transmission systems for Fixed Broadband Wireless Access (BWA) based on cable modem standards (Annex B of J.112)

[3] ITU-T Recommendation J.112 “Transmission systems for interactive cable television services"

[4] ITU-T Recommendation J.83 "Digital multiprogramme systems for television, sound and data services for cable distribution”

[5] IEEE 802.16MC-99/03 “MAC document based on DOCSIS 1.1 (SP-RFv1.1-I02-990731), Phasecom

[6] Data-over-Cable Interface Specifications, Security System interface specification, SP-SSI-I01-970506

[7] Data-Over-Cable Interface Specifications, Baseline Privacy Interface Specification, SP-BPI-I01-970609

[8] ITU-T Recommendation H.222 “Information Technology-generic coding of moving pictures and associated audio information systems”