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MULTIMEDIA SIGNALS

Interactive systems for digital television distribution

Downstream external Physical layer interface for modular cable modem termination systems

ITU-T Recommendation J.212



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Downstream external Physical layer interface for modular cable modem termination systems

Summary

This Recommendation defines an interface known as the Downstream External PHY Interface (DEPI) and associated protocol requirements for the transport of downstream user data between the "M-CMTS Core" and the EQAM. It describes the characteristics of the DEPI interface, provides requirements that must be met by the M-CMTS Core and the EQAM, and also describes various aspects of technical issues that are involved in the implementation and deployment of a DOCSIS system using the M-CMTS architecture.

Source

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CONTENTS

Page

1	Scope	1
2	References.....	2
2.1	Normative references.....	2
2.2	Informative references.....	2
2.3	Reference acquisition	3
3	Terms and definitions	3
4	Abbreviations, acronyms and conventions.....	6
4.1	Abbreviations and acronyms	6
4.2	Conventions	8
5	Technical overview.....	9
5.1	System architecture	9
5.2	Bonding services model	13
5.3	Multiple services model	13
6	DEPI architecture.....	14
6.1	DEPI Data Path.....	14
6.2	Networking considerations.....	18
6.3	System timing considerations.....	20
7	DEPI control plane	20
7.1	Topology.....	21
7.2	Addressing.....	21
7.3	Control message format.....	23
7.4	Signalling.....	27
7.5	AVP definitions	33
8	DEPI forwarding plane	47
8.1	L2TPv3 transport packet format.....	47
8.2	DOCSIS MPT mode.....	50
8.3	PSP mode.....	51
8.4	DEPI latency measurement (DLM) sublayer header.....	52
8.5	M-CMTS core output rate	53
	Annex A – DEPI MTU	54
A.1	L2TPv3 lower layer payload size	54
A.2	Maximum frame size for DEPI	54
A.3	Path MTU discovery.....	55
	Annex B – Parameters and constants	55
	Appendix I – DEPI and DOCSIS system performance	56
I.1	Introduction	56
I.2	Round-trip time and performance	56

	Page
I.3 Elements of round-trip time.....	56
I.4 CIN characteristics	58
I.5 Queueing delays in network elements	59
I.6 Traffic prioritization and network delays	60
I.7 Queue persistence in a DEPI flow	60
I.8 PSP mode.....	62
Appendix II – Early adoption and evolving use of EQAM devices	63
II.1 EQAM development: Category A (no DTI).....	63
II.2 EQAM development: Category B (with DTI).....	64
II.3 Possible M-CMTS feature phasing	64
II.4 Optional UDP layer	65

iv

ITU-T Recommendation J.212

Downstream external Physical layer interface for modular cable modem termination systems

1 Scope

This Recommendation is part of the DOCSIS[®] family of Recommendations that define a Modular Cable Modem Termination System (M-CMTS[™]) architecture for head-end components that comply with DOCSIS.

The DOCSIS Recommendations [J.122] define the requirements for the two fundamental components that comprise a high-speed data-over-cable system: the cable modem (CM) and the cable modem termination system (CMTS). The M-CMTS architecture was designed as an extension to the DOCSIS Recommendations to allow for flexibility and independent scaling of certain CMTS functions, and to allow operators to more efficiently use available network resources.

One of the key elements of the M-CMTS architecture is the separation of the downstream physical layer QAM modulation and up-conversion functions from the CMTS, and the placement of that functionality into an "Edge-QAM" (EQAM) device. This separation allows for the development of EQAM products that support both video and DOCSIS, which in turn allows operators to use the same network resources to support multiple types of services such as data, voice and video.

This Recommendation defines an interface known as the Downstream External PHY Interface (DEPI) and associated protocol requirements for the transport of downstream user data between the "M-CMTS Core" and the EQAM. It describes the characteristics of the DEPI interface, provides requirements that must be met by the M-CMTS Core and the EQAM, and also describes various aspects of technical issues that are involved in the implementation and deployment of a DOCSIS system using the M-CMTS architecture.

Two different master clock frequency options are available within the M-CMTS architecture. The first option, a 10.24 MHz master clock is used in the Americas, Europe and other regions. The second option, a 9.216 MHz master clock is used in Japan. Compliance with this Recommendation requires compliance with the one or the other of these implementations, not with both. It is not required that equipment built to one option shall interoperate with equipment built to the other.

A list of the documents in the Modular CMTS Interface Recommendations family is provided below.

Designation	Title
J.212	Downstream External PHY Interface
J.211	DOCSIS Timing Interface
CM-SP-ERMI	Edge Resource Manager Interface, CM-SP-ERMI-I02-051209, 9 December 2005, Cable Television Laboratories, Inc.
CM-SP-M-OSSI	M-CMTS Operations Support System Interface, CM-SP-M-OSSI-I02-051209, 9 December 2005, Cable Television Laboratories, Inc.

2 References

2.1 Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [H.222.0] ITU-T Recommendation H.222.0 (2006) | ISO/IEC 13818-1:2007, *Information technology – Generic coding of moving pictures and associated audio information: Systems*.
- [J.83] ITU-T Recommendation J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution*.
- [J.122] ITU-T Recommendation J.122 (2002), *Second-generation transmission systems for interactive cable television services – IP cable modems*.
- [J.210] ITU-T Recommendation J.210 (2006), *Downstream RF interface for Cable Modem Termination Systems*.
- [J.211] ITU-T Recommendation J.211 (2006), *Timing interface for Cable Modem Termination Systems*.
- [IANA-PORTS] IANA (2004), *Port Numbers*.
- [IEEE-802.1Q] IEEE Std 802.1Q-2005, *IEEE Standard for Local and Metropolitan Area Networks – Virtual Bridged Local Area Networks*.
- [IEEE-802.3] IEEE Std 802.3-2005, *IEEE Standard for information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier Sense Multiple Access With Collision Detection (CSMA/CD) Access Method And Physical Layer Specification*.
- [RFC-IP] IETF RFC 791 (1981), *Internet Protocol – DARPA Internet Program – Protocol specification*.
- [RFC-L2TP-DSCP] IETF RFC 3308 (2002), *Layer Two Tunnelling Protocol (L2TP) Differentiated Services Extension*.
- [RFC-L2TPv3] IETF RFC 3931 (2005), *Layer Two Tunnelling Protocol – Version 3 (L2TPv3)*.
- [RFC-MTU] IETF RFC 1191 (1990), *Path MTU Discovery*.
- [RFC-PHBID-AF] IETF RFC 2597 (1999), *Assured Forwarding PHB Group*.
- [RFC-PHBID-EF] IETF RFC 3246 (2002), *An Expedited Forwarding PHB (Per-Hop Behaviour)*.
- [RFC-UDP] IETF RFC 768 (1980), *User Datagram Protocol*.

2.2 Informative references

- [DVB-RF] ETSI EN 300 429 V1.2.1 (1998), *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems*.

- [ERMI] *Edge Resource Manager Interface*, CM-SP-ERMI-I02-051209, 9 December 2005, Cable Television Laboratories, Inc.
- [ISO 8802-2] ISO/IEC 8802-2:1998 (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*.
- [MOSSI] *DOCSIS M-CMTS Operations Support Interface*, CM-SP-M-OSSI-I02-051209, 9 December 2005, Cable Television Laboratories, Inc.
- [RFC-DSCP-1] IETF RFC 2983 (2000), *Differentiated Services and Tunnels*.
- [RFC-DSCP-2] IETF RFC 3260 (2002), *New Terminology and Clarifications for Diffserv*.
- [VCCV] IETF draft-ietf-pwe3-vccv-12.txt, *Pseudo Wire Virtual Circuit Connectivity Verification (VCCV)*, January 2007.

2.3 Reference acquisition

- Cable Television Laboratories, Inc., Internet: <http://www.cablelabs.com/>; <http://www.cablemodem.com/specifications/>
- The Institute of Electrical and Electronics Engineers, Inc, Internet: <http://standards.ieee.org>
- Internet Engineering Task Force (IETF), Internet: <http://www.ietf.org>
- Internet Assigned Numbers Authority, IANA, Internet: <http://www.iana.org>
- European Telecommunications Standards Institute, ETSI, <http://www.etsi.org>

3 Terms and definitions

This Recommendation defines the following terms:

- 3.1 bonded channels:** A logical channel comprising multiple individual channels.
- 3.2 cable modem (CM):** A modulator-demodulator at subscriber locations intended for use in conveying data communications on a cable television system.
- 3.3 converged interconnect network:** The network (generally gigabit Ethernet) that connects an M-CMTS Core to an EQAM.
- 3.4 customer premises equipment (CPE):** Equipment at the end user's premises; may be provided by the service provider.
- 3.5 data rate:** Throughput, data transmitted in units of time usually in bits per second (bit/s).
- 3.6 decibels (dB):** Ratio of two power levels expressed mathematically as $\text{dB} = 10\log_{10}(P_{\text{OUT}}/P_{\text{IN}})$.
- 3.7 decibel-millivolt (dBmV):** Unit of RF power expressed in decibels relative to 1 millivolt, where $\text{dBmV} = 20\log_{10}(\text{value in mV}/1 \text{ mV})$.
- 3.8 downstream (DS):**
- 1) Transmissions from CMTS to CM. This includes transmission from the M-CMTS Core to the EQAM as well as the RF transmissions from the EQAM to the CM.
 - 2) RF spectrum used to transmit signals from a cable operator's headend or hub site to subscriber locations.
- 3.9 edge QAM modulator (EQAM):** A headend or hub device that receives packets of digital video or data. It re-packetizes the video or data into an MPEG transport stream and digitally modulates the digital transport stream onto a downstream RF carrier using quadrature amplitude modulation (QAM).

3.10 flow: A stream of packets in DEPI used to transport data of a certain priority from the M-CMTS Core to a particular QAM channel of the EQAM. In PSP operation, there can exist several flows per QAM channel.

3.11 GigE (GE): Gigabit Ethernet (1 Gbit/s).

3.12 hybrid fibre/coax (HFC) system: A broadband bidirectional shared-media transmission system using optical fibre trunks between the headend and the fibre nodes, and coaxial cable distribution from the fibre nodes to the customer locations.

3.13 Institute of Electrical and Electronics Engineers (IEEE): A voluntary organization which, among other things, sponsors standards committees and is accredited by the American National Standards Institute (ANSI).

3.14 Internet Engineering Task Force (IETF): A body responsible for, among other things, developing standards used in the Internet.

3.15 Internet Protocol (IP): An Internet network-layer protocol.

3.16 L2TP access concentrator (LAC): If an L2TP Control Connection Endpoint (LCCE) is being used to cross-connect an L2TP session directly to a data link, we refer to it as an L2TP Access Concentrator (LAC). An LCCE may act as both an L2TP Network Server (LNS) for some sessions and LAC for others, so these terms must only be used within the context of a given set of sessions unless the LCCE is in fact single purpose for a given topology.

3.17 L2TP attribute value pair (AVP): The L2TP variable-length concatenation of a unique Attribute (represented by an integer), a length field, and a Value containing the actual value identified by the attribute.

3.18 L2TP control connection: An L2TP control connection is a reliable control channel that is used to establish, maintain, and release individual L2TP sessions as well as the control connection itself.

3.19 L2TP control connection endpoint (LCCE): An L2TP node that exists at either end of an L2TP control connection. May also be referred to as LAC or LNS, depending on whether tunnelled frames are processed at the data link (LAC) or network layer (LNS).

3.20 L2TP control connection ID: The Control Connection ID field contains the identifier for the control connection, a 32-bit value. The Assigned Control Connection ID AVP, Attribute Type 61, contains the ID being assigned to this control connection by the sender. The Control Connection ID specified in the AVP must be included in the Control Connection ID field of all control packets sent to the peer for the lifetime of the control connection. Because a Control Connection ID value of 0 is used in this special manner, the zero value must not be sent as an Assigned Control Connection ID value.

3.21 L2TP control message: An L2TP message used by the control connection.

3.22 L2TP data message: An L2TP message used by the data channel.

3.23 L2TP endpoint: A node that acts as one side of an L2TP tunnel.

3.24 L2TP network server (LNS): If a given L2TP session is terminated at the L2TP node and the encapsulated network layer (L3) packet processed on a virtual interface, we refer to this L2TP node as an L2TP Network Server (LNS). A given LCCE may act as both an LNS for some sessions and LAC for others, so these terms must only be used within the context of a given set of sessions unless the LCCE is in fact single purpose for a given topology.

3.25 L2TP pseudowire (PW): An emulated circuit as it traverses a packet-switched network. There is one Pseudowire per L2TP Session.

- 3.26 L2TP pseudowire type:** The payload type being carried within an L2TP session. Examples include PPP, Ethernet, and Frame Relay.
- 3.27 L2TP session:** An L2TP session is the entity that is created between two LCCEs in order to exchange parameters for and maintain an emulated L2 connection. Multiple sessions may be associated with a single Control Connection.
- 3.28 L2TP session ID:** A 32-bit field containing a non-zero identifier for a session. L2TP sessions are named by identifiers that have local significance only. That is, the same logical session will be given different Session IDs by each end of the control connection for the life of the session. When the L2TP control connection is used for session establishment, session IDs are selected and exchanged as Local Session ID AVPs during the creation of a session. The Session ID alone provides the necessary context for all further packet processing, including the presence, size, and value of the Cookie, the type of L2-Specific Sublayer, and the type of payload being tunnelled.
- 3.29 MAC domain:** A grouping of layer 2 devices that can communicate with each other without using bridging or routing. In DOCSIS, it is the group of CMs that are using upstream and downstream channels linked together through a MAC forwarding entity.
- 3.30 maximum transmission unit (MTU):** The layer 3 payload of a layer 2 frame.
- 3.31 media access control (MAC):** Used to refer to the layer 2 element of the system which would include DOCSIS framing and signalling.
- 3.32 modulation error ratio (MER):** The ratio of the average symbol power to average error power.
- 3.33 physical media dependent (PMD) sublayer:** A sublayer of the Physical layer which is concerned with transmitting bits or groups of bits over particular types of transmission link between open systems and which entails electrical, mechanical and handshaking procedures.
- 3.34 QAM channel (QAM ch):** Analog RF channel that uses quadrature amplitude modulation (QAM) to convey information.
- 3.35 quadrature amplitude modulation (QAM):** A modulation technique in which an analog signal's amplitude and phase vary to convey information, such as digital data.
- 3.36 radio frequency (RF):** In cable television systems, this refers to electromagnetic signals in the range 5 to 1000 MHz.
- 3.37 radio frequency interface (RFI):** Term encompassing the downstream and the upstream radio frequency interfaces.
- 3.38 request for comments (RFC):** A technical policy document of the IETF; these documents can be accessed on the World Wide Web at <http://www.rfc-editor.org/>.
- 3.39 session:** An L2TP data plane connection from the M-CMTS Core to the QAM channel. There must be one session per QAM Channel. There is one DEPI pseudowire type per session. There may be one MPT flow or one or more PSP flows per session. Multiple sessions may be bound to a single control connection.
- 3.40 StopCCN:** L2TPv3 Stop-Control-Connection-Notification message.
- 3.41 upconverter:** A device used to change the frequency range of an analog signal, usually converting from a local oscillator frequency to an RF transmission frequency.
- 3.42 upstream (US):**
- 1) Transmissions from CM to CMTS. This includes transmission from the EQAM to M-CMTS Core as well as the RF transmissions from the CM to the EQAM.
 - 2) RF spectrum used to transmit signals from a subscriber location to a cable operator's headend or hub site.

3.43 upstream channel descriptor (UCD): The MAC Management Message used to communicate the characteristics of the upstream physical layer to the cable modems.

3.44 video-on-demand (VoD) system: System that enables individuals to select and watch video content over a network through an interactive television system.

4 Abbreviations, acronyms and conventions

4.1 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

ACK	L2TPv3 Explicit Acknowledgement message
AVP	L2TPv3 Attribute Value Pair
CDN	L2TPv3 Call-Disconnect-Notify message
CIN	Converged Interconnect Network
CLI	Command Line Interface
CM	Cable Modem
CMCI	Cable Modem CPE Interface
CMTS	Cable Modem Termination System
CPE	Customer Premises Equipment
CRC	Cyclic Redundancy Check
CRC-16	CRC of length 16
CSMA	Carrier Sense Multiple Access
DEPI	Downstream External PHY Interface
DOCSIS	Data-Over-Cable Service Interface Specifications
DOCSIS-MPT (D-MPT)	DOCSIS MPT Mode
DRFI	Downstream Radio Frequency Interface
DS	Downstream
DSCP	Differentiated Services Code Point
DTI	DOCSIS Timing Interface
DTS	DOCSIS Time Stamp, 32 bits
EQAM	Edge QAM
ERM	Edge Resource Manager
ERMI	Edge Resource Manager Interface
ETSI	European Telecommunications Standards Institute
FQDN	Fully Qualified Domain Name
GE	Gigabit Ethernet (GigE)
HELLO	L2TPv3 Hello message
HFC	Hybrid Fibre/Coax
ICCN	L2TPv3 Incoming-Call-Connected message

ICRP	L2TPv3 Incoming-Call-Reply message
ICRQ	L2TPv3 Incoming-Call-Request message
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet Protocol version 4
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
L2TP	Layer 2 Transport Protocol
L2TPv3	Layer 2 Transport Protocol – Version 3
L3	Layer 3
LAC	L2TP Access Concentrator
LCCE	L2TP Control Connection Endpoint
LNS	L2TP Network Server
LSB	Least Significant Bit
M/N	Relationship of integer numbers M,N that represents the ratio of the downstream symbol clock rate to the DOCSIS master clock rate
MAC	Media Access Control
M-CMTS	Modular Cable Modem Termination System
MER	Modulation Error Ratio
MIB	Management Information Base
MPEG	Moving Picture Experts Group
MPEG-TS	Moving Picture Experts Group Transport Stream
MPT	MPEG-TS mode of DEPI
MPTS	Multi-Program Transport Stream
MSB	Most Significant Bit
MTU	Maximum Transmission Unit
OSSI	Operations Support System Interface
PCR	Program Clock Reference. A time stamp in the Video Transport Stream from which decoder timing is derived.
PHY	Physical Layer
PID	Packet Identifier; PID (system): A unique integer value used to identify elementary streams of a program in a single or multi-program Transport Stream as described in 2.4.3 of [H.222.0 ISO 13818-1]
PMD	Physical Media Dependent Sublayer
PPP	Point-to-Point Protocol

PSI	Program Specific Information
PSP	Packet Streaming Protocol
PW	Pseudowire
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RFC	Request For Comments
RFI	Radio Frequency Interface
SCCCN	L2TPv3 Start-Control-Connection-Connected message
SCCRP	L2TPv3 Start-Control-Connection-Reply message
SCCRQ	L2TPv3 Start-Control-Connection-Request message
S-CDMA	Synchronous Code Division Multiple Access
SLI	L2TPv3 Set Link Info message
SPTS	Single Program Transport Stream
StopCCN	L2TPv3 Stop-Control-Connection-Notification message
TSID	MPEG2 Transport Stream ID
UCD	Upstream Channel Descriptor
UDP	User Datagram Protocol
US	Upstream
VoD	Video-on-Demand

4.2 Conventions

In this Recommendation, the following convention applies any time a bit field is displayed in a figure. The bit field should be interpreted by reading the figure from left to right, then from top to bottom, with the MSB being the first bit so read and the LSB being the last bit so read.

Throughout this Recommendation, the words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST"	This word or the adjective "REQUIRED" means that the item is an absolute requirement of this Recommendation.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this Recommendation.
"SHOULD"	This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
"MAY"	This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product; for example, another vendor may omit the same item.

5 Technical overview

This clause is informative.

5.1 System architecture

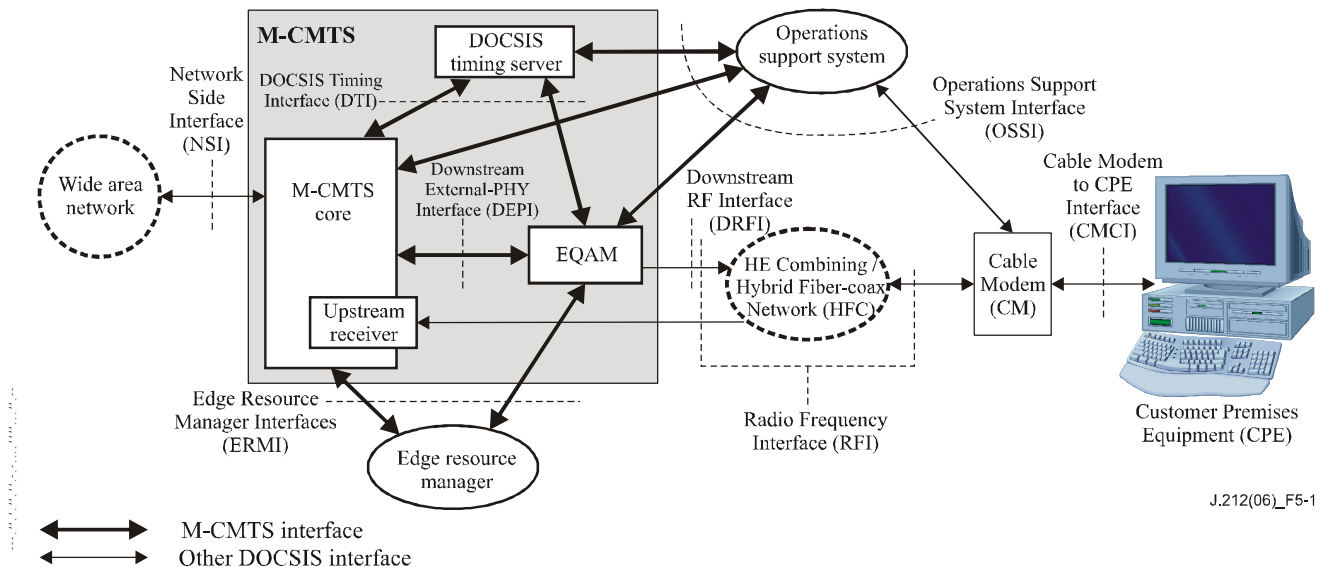


Figure 5-1/J.212 – Modular CMTS reference architecture

In the M-CMTS architecture, a device referred to as the M-CMTS Core contains the DOCSIS MAC. This includes all signalling functions, downstream bandwidth scheduling, and DOCSIS framing. The EQAM box contains mainly PHY related circuitry, such as QAM modulators, and tunnelling logic, to connect to the M-CMTS Core.

5.1.1 Reference architecture

The reference architecture for a Modular CMTS system is shown in Figure 5-1. This architecture contains several pieces of equipment along with interfaces between those pieces of equipment. This clause will briefly introduce each device and interface.

The Edge QAM device, or EQAM for short, has its origins in the VoD environment. This device typically has one or more gigabit Ethernet interfaces and multiple QAM modulators and RF upconverters. This EQAM is being adapted for use in a Modular CMTS environment. Each individual output of these devices is often referred to as QAM Channel rather than the combination "QAM Modulator and RF Upconverter".

The M-CMTS Core contains everything a traditional CMTS does, except for functions performed in the EQAM. The M-CMTS Core contains the downstream MAC and all the initialization and operational DOCSIS related software.

This diagram shows the Upstream Receivers of DOCSIS upstream channels located internally to the M-CMTS Core. However, there is nothing preventing an implementation of a Modular CMTS from using a proprietary external upstream receiver interface. In the future, an interface may be defined between the M-CMTS Core and external upstream receivers.

The DOCSIS Timing Interface (DTI) Server provides a common master clock frequency and a DOCSIS timestamp to other M-CMTS elements.

DEPI, the Downstream External PHY Interface, is the interface between the M-CMTS Core and the EQAM. More specifically, it is an IP Tunnel between the MAC and PHY in a Modular CMTS

system which contains both a data path for DOCSIS frames, and a control path for setting up, maintaining, and tearing down sessions.

DRFI, or Downstream Radio Frequency Interface, is intended to capture all the current and future RF requirements for the downstream direction for both integrated DOCSIS CMTS systems, Modular DOCSIS CMTS systems, and VoD EQAM systems.

DTI, or DOCSIS Timing Interface, is a point-to-point interface from the DTI Server to other M-CMTS elements. The DTI Recommendation [J.211] defines DTI Server and DTI Client behaviours and protocols. The DTI Server is the Timing Signal Generator while each M-CMTS Core and EQAM has a DTI Client. The DTI Server distributes a DOCSIS master clock and a DOCSIS timestamp over unshielded twisted pair (UTP). The DTI protocol automatically compensates for cable length and ensures that all M-CMTS elements have the same sense of time and frequency.

ERMI, or Edge Resource Manager Interface [ERMI], involves three interfaces: a registration interface between an EQAM and ERM (Edge Resource Manager), a control interface between an EQAM and an ERM, and a control interface between an M-CMTS Core and an ERM. The first interface is used to register and unregister EQAM resources (i.e., QAM channels) with an ERM. The second interface is used by an ERM to request QAM channel resources from an EQAM, and by an EQAM to deliver resources to an ERM. The third interface is used by the M-CMTS Core to request specific QAM channel resources from the ERM, and by the ERM to respond to such requests with the location of QAM channel resources.

MOSSI, or Modular CMTS Operations Support System Interface [MOSSI], provides the management interface to each system component. This interface is an extension of the OSSI defined in the DOCSIS Recommendations for monitoring a management of CMTS functions. This interface could be used, in place of an ERM and the ERMI, to statically configure and associate QAM channel resources with M-CMTS Cores. This interface allows for the modification of a QAM channel's physical layer parameter by either the M-CMTS Core or the EQAM, and provides a mechanism by which the operator can "lock" certain parameters at the EQAM so that they can only be modified there. This Recommendation defines the mechanism to communicate these parameter settings to the other side.

NSI, or the Network Side Interface, is unchanged, and is the physical interface the CMTS uses to connect to the backbone network. Today, this is typically 100 Mbit/s or 1 Gbit/s Ethernet.

CMCI, or Cable Modem to Customer Premises Equipment Interface, is also unchanged, and is typically 10/100 Mbit/s Ethernet or USB.

5.1.2 DEPI operation

DEPI is an IP Tunnel that exists between the DOCSIS MAC in the M-CMTS Core and the DOCSIS PHY that exists in the EQAM. DEPI's job is to take either formatted DOCSIS frames or MPEG packets and transport them through a layer 2 or layer 3 network and deliver them to the EQAM for transmission.

The base protocol that is used for the DEPI is the Layer 2 Tunnelling Protocol Version 3, or L2TPv3 for short [RFC-L2TPv3]. L2TPv3 is an IETF protocol that is a generic protocol for creating a pseudowire. A pseudowire is a mechanism to transparently transport a layer 2 protocol over a layer 3 network. Examples of protocols supported by L2TPv3 include ATM, HDLC, Ethernet, Frame Relay, PPP, etc.

Clause 8.1 "L2TPv3 Transport Packet Format" shows the format of an L2TPv3 data packet. Each data packet contains a 32-bit session ID which is associated with a single QAM Channel on the EQAM. The UDP header is optional in the L2TPv3 protocol. In the DEPI protocol, both the EQAM and the M-CMTS core are required to support the ability to include the UDP header in both the control plane and the forwarding plane (see 7.3). Support for DEPI operation without the

UDP header is optional for both the EQAM and M-CMTS core, and can be used if both ends support it, as described in clauses 7.3 and 8.

L2TPv3 then permits a sub-header to exist whose definition is specific to the payload being carried. The control channel allows for signalling messages to be sent between the M-CMTS Core and EQAM. Typical control messages will set up a "control connection" between the M-CMTS Core and EQAM, and then set up multiple data sessions (one for each downstream QAM channel). Each session can utilize different DiffServ Code Points (DSCPs), and support different encapsulation protocols.

There are two basic tunnelling techniques defined by DEPI. The first technique, known as D-MPT mode, transports multiple 188-byte MPEG-TS packets by placing them into the L2TPv3 payload with a unique sub-header which contains a sequence number so packet drops can be detected. The encapsulation of DOCSIS Frames into MPEG-TS packets is performed in the M-CMTS Core. The second technique, known as the Packet Streaming Protocol (PSP), transports DOCSIS Frames in the L2TPv3 payload. The DOCSIS Frames are then encapsulated in MPEG-TS packets within the EQAM. PSP mode allows DOCSIS frames to be both concatenated, to increase network performance, and fragmented, in case the tunnelled packets exceed the network MTU size.

One of the technical considerations of the Modular CMTS architecture is its impact on the round trip request-grant delay time. The request-grant delay time is the time from when a CM requests bandwidth using an uncontended bandwidth request (REQ) to when it receives a MAP message with the granted transmit opportunity in it.

To prevent the MAP from being slowed down by other traffic in the CIN, the DOCSIS traffic (or a subset containing the MAP messages) may be sent in an independent L2TPv3 flow that has a unique DSCP. This DSCP will have a "per hop behaviour (PHB)" that will give MAPs the highest priority and lowest latency service.

5.1.3 EQAM Operation

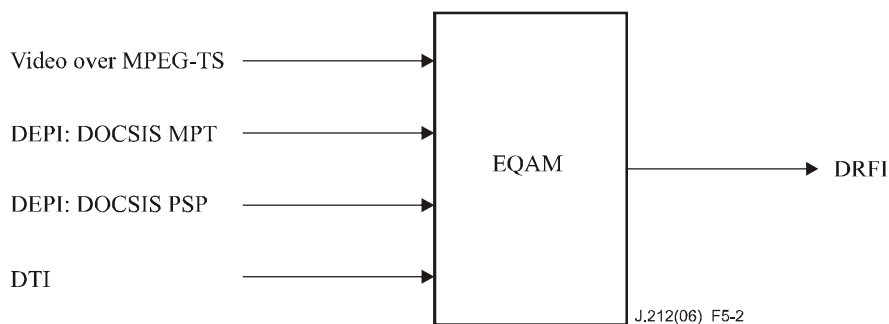


Figure 5-2/J.212 – EQAM block diagram

Figure 5-2 shows a high level block diagram of an EQAM that is capable of handling either Video MPEG traffic or DOCSIS traffic. The expression "D-MPT" is an acronym for DOCSIS MPEG Transport.

The first interface that is shown is the VoD transport. VoD SPTS or MPTS streams are received with a format of MPEG packets over UDP/IP. The video processing functions generally include de-jittering, re-multiplexing PID remapping, MPEG-2 PSI insertion, and PCR timestamp correction. These functions are not defined in this Recommendation.

The next set of interfaces are the DEPI interfaces.

The first interface defined is D-MPT. This is a mode where the EQAM must search the incoming D-MPT frames for DOCSIS SYNC messages and correct the timestamp value in these messages based upon the EQAM's internal DOCSIS timestamp which has been derived from DTI. The resulting D-MPT frames are then copied to the QAM channel without further interpretation or modification. This mode is intended for DOCSIS frames where the MAP is embedded into the stream and network latency or jitter is not a concern.

Because D-MPT mode encapsulates all DOCSIS traffic into a single DEPI flow, it does not allow for QoS differentiation among various types of traffic either across the CIN or within the EQAM. For example, acceleration of MAPs relative to other DOCSIS data is not possible when D-MPT mode is used. This may still give acceptable performance when the delay and jitter introduced onto DEPI packets by the CIN and EQAM are determined by the operator to be sufficiently low.

Certain network conditions and/or architectures may reduce network delay and/or jitter and make it more likely that DOCSIS MPT mode will give acceptable system performance. Some examples are:

- networks with a very small number of hops (e.g., 1 or 2 hops), especially if these hops are all switches (which generally introduce less delay and jitter than routers);
- networks which are largely shared with video traffic from VoD servers to EQAMs, on which most of the traffic is video and it is acceptable to prioritize all DEPI traffic on the network above all VoD traffic;
- networks which are lightly loaded so that delays due to congestion are highly unlikely.

Such conditions may exist on today's CINs. They may be less likely to occur as deployments become denser and total IP traffic increases. Evaluation of network conditions and decisions about acceptable performance levels with DOCSIS MPT mode are in the realm of operator discretion.

The next interface is DOCSIS PSP. This interface transports DOCSIS Data and MAPs in separate flows which are streamed together in a uniform byte stream by the M-CMTS Core. The PSP re-assembly engine removes this overhead and recovers the DOCSIS Frames. The PSP scheduler then allows MAPs to be placed in order, ahead of data and SYNC messages. In PSP mode, the EQAM generates all SYNC messages as detailed in 6.1.1. The output is then delivered to a transmission convergence layer which converts the results to a DOCSIS MPEG stream.

The last interface is the DTI interface which provides a common frequency and DOCSIS timestamp. The reference is used to synchronize the downstream symbol rate and DOCSIS timestamp for use with DOCSIS cable modems. The timestamp is used for the DOCSIS SYNC correction.

The output from the EQAM consists of a stream of MPEG frames which carry video and/or DOCSIS data, and are modulated onto an RF carrier in accordance with the DRFI Recommendation [J.210].

5.2 Bonding services model

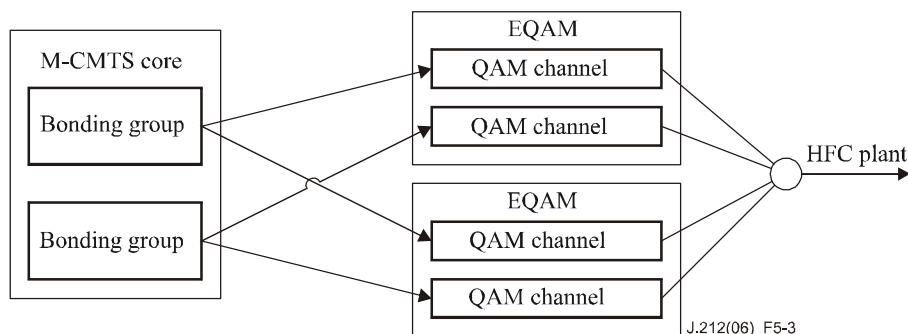


Figure 5-3/J.212 – Bonding services model

Downstream Channel Bonding refers to the forwarding of a stream of DOCSIS frames across multiple QAM carriers.

In the Modular CMTS architecture, the Downstream Channel Bonding is implemented in the M-CMTS Core. At the M-CMTS Core, packets from the IP backbone are placed in a DOCSIS frame. That DOCSIS frame is then sent to one of several QAM channels in a Bonding Group. The frame may be transported using D-MPT or PSP.

In this system, the EQAM is unaware that it is doing bonding. It is also unaware of any of the details of the Bonding protocol.

5.3 Multiple services model

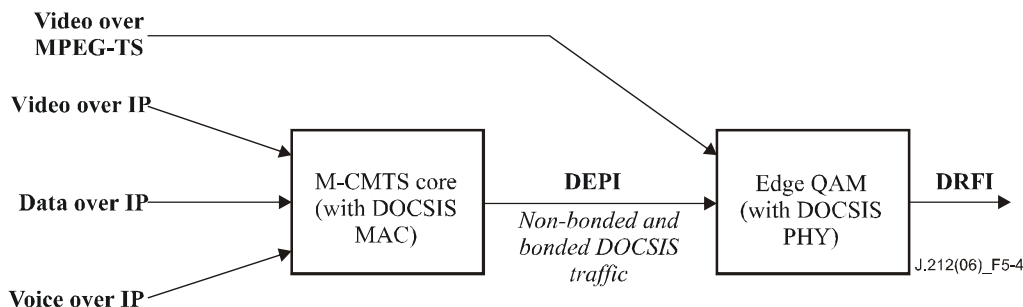


Figure 5-4/J.212 – Multi-service mode

The Modular CMTS (M-CMTS) architecture reflects an effort to merge the video-on-demand (VoD) and high speed data (HSD) applications. This effort is made in anticipation of achieving higher efficiencies than are possible with two separate transmission networks feeding into the cable plant. In particular, the M-CMTS effort has repartitioned the traditional CMTS architecture so that the transmission technology which is common to both the VoD environment and the HSD environment will be able to share the same EQAM devices.

In a video delivery system, the EQAM is used to deliver video streams in MPEG-TS format to set top boxes at the subscribers' premises. This functionality will continue to be used in the future and operates independently of other processing which is described here. The M-CMTS architecture adds new interfaces which are unique to HSD service. These interfaces support both traditional DOCSIS and multichannel (bonded) DOCSIS payloads as received from the M-CMTS Core device.

The M-CMTS Core provides the gateway functionality between the IP-based core network and the CIN. As such, the M-CMTS Core provides support for a multitude of services – including, but not limited to video over IP, voice-over-IP (VoIP), email, gaming, video telephony, etc.

6 DEPI architecture

This clause is normative.

6.1 DEPI Data Path

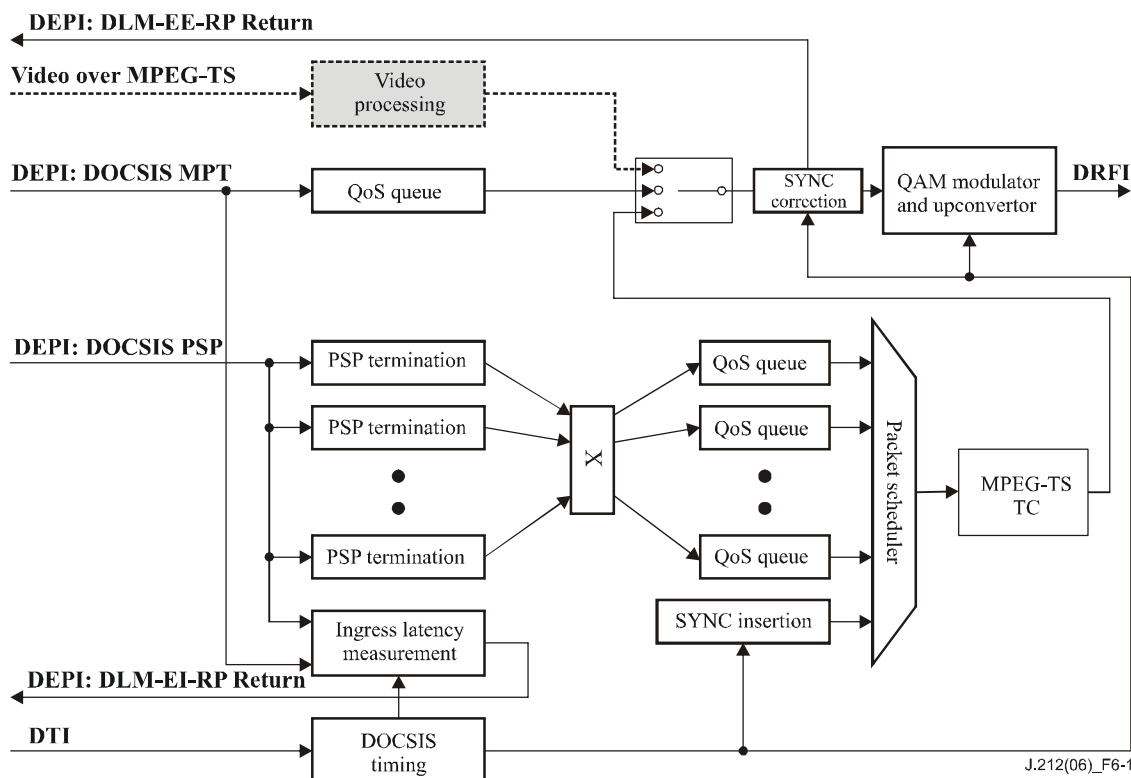


Figure 6-1/J.212 – Downstream EQAM block diagram

A simplified logical block diagram of the internal data path of the EQAM is shown in Figure 6-1.

It is recognized, but not specified by this Recommendation, that the EQAM may receive non-DOCSIS MPEG elementary streams which have been encapsulated in MPEG packets and placed in a UDP datagram. This Recommendation does not define requirements for transport of this type of traditional MPEG video. However, it is recognized that M-CMTS EQAM implementations may (and likely will) be capable of transporting traditional MPEG video (either interleaved with DOCSIS traffic on a single QAM channel, or on separate QAM channels within the same EQAM chassis).

The M-CMTS Core MUST support PSP mode, D-MPT mode, or both. The EQAM MUST support PSP mode, D-MPT mode, or both.

Within a session, the M-CMTS Core MUST support either one priority level of D-MPT or at least two priority levels of PSP, where each priority level would have a different DSCP. The M-CMTS Core MUST provide a mechanism to map DOCSIS traffic to the multiple priority levels of PSP. The M-CMTS Core MUST NOT attempt to establish a session which includes both PSP and D-MPT flows.

Within a session, the EQAM MUST support either one priority level of D-MPT or at least two priority levels of PSP, where each priority level would have a different DSCP. The EQAM is not intended to simultaneously support D-MPT and PSP within a single session, and MUST reject any attempt to establish such a session. Each priority level for each DEPI type, maps to one or more DEPI flows. The EQAM MUST support the establishment of a single DEPI flow per priority level. The EQAM MAY support the establishment of more than one DEPI flow per priority level. The mapping of individual flows to priority levels (QoS Queues) is vendor-specific (see Figure 7-3). The mapping of flows will be done through the local EQAM Command Line Interface (CLI) configuration.

For both D-MPT and PSP modes, the EQAM MUST insert null MPEG packets when it has no data to send. The EQAM SHOULD NOT insert a null MPEG packet if it has data to send. Note that MPEG null insertion should take place prior to the correction of the DOCSIS SYNC message (refer to 6.1.1).

6.1.1 DOCSIS D-MPT data path

The DEPI DOCSIS D-MPT flows contain DOCSIS frames using the format as described in 8.2. All DOCSIS frames, including packet based frames and MAC management based frames, are included within the one D-MPT flow. The EQAM searches the D-MPT payload for any DOCSIS SYNC messages and performs SYNC corrections as described in 6.1.3.2. It then forwards the D-MPT packet to the RF interface.

The intent of D-MPT mode is that MPEG packets can be received by the EQAM and forwarded directly to the RF interface without having to terminate and regenerate the MPEG framing. The only manipulation of the D-MPT payload is the SYNC correction.

6.1.2 PSP data path

The Packet Stream Protocol (PSP) is a layer-3 convergence layer protocol, which allows packets to be consecutively streamed together and fragmented at arbitrary boundaries. The intent of the PSP mode is to facilitate Quality of Service. This mode is to be used for transporting traditional DOCSIS data and signalling messages which use one or more DSCP values. For example, in order to reduce Request-Grant latency, MAP MAC management messages may be sent using a different DSCP on a different PSP flow than the rest of the DOCSIS channel. Refer to 6.2.1 for more information. The EQAM MUST support a minimum of two PSP receivers per QAM modulator. The intent of two receivers is to permit the implementation of a higher latency PSP flow and a lower latency PSP flow.

Each PSP flow is terminated, and the DOCSIS Frames within the flow are extracted. The DOCSIS frames are placed into corresponding output QoS queues. The output of the QoS queues go to a Packet Scheduler, which decides which queue is to be serviced based upon the PHB (negotiated between the M-CMTS Core and EQAM) of the PSP flow, which carried the DOCSIS frames. The Packet Scheduler is also responsible for inserting DOCSIS SYNC messages within the time interval specified by the DOCSIS SYNC Control AVP (see Figure 7-31). The Packet Scheduler SHOULD support a strict priority scheduler. The Packet Scheduler MAY support other queue scheduling disciplines.

The phrase "packet scheduler" is a general term that describes a method of applying priorities to different queues as packets are moved from different input queues to the output queue. An example of a typical Packet Scheduling algorithm would be Weighted Fair Queuing (WFQ) where some streams are given priority over other streams, but only up to some limit. This should not be confused with the more complex DOCSIS upstream scheduler, which deals with requests and grants.

The output of the Packet Scheduler goes to a Transmission Convergence engine which places the DOCSIS frames into MPEG packets according to the requirements in [J.210]. This includes the

insertion of stuffing bytes and the DOCSIS SYNC message as described by 6.1.3. The output of Transmission Convergence (TC) engine is sent to the RF Interface.

PSP mode primarily provides acceleration of MAPs through the network, in an attempt to reduce Request Grant latency. The PSP mode is most useful when all or most traffic has migrated to DOCSIS, and therefore, marking MAPs with higher QoS, when compared to other DOCSIS traffic that is needed in order to provide lower latency for MAPs, when traversing a fully subscribed network. Therefore, PSP has value in the long term and is included to address the case where most or all traffic is carried to the home via DOCSIS.

6.1.3 DOCSIS SYNC message

6.1.3.1 SYNC message format

The DOCSIS Time Synchronization (SYNC) MAC message is transmitted by a Modular CMTS system at a periodic interval to establish MAC sublayer timing in cable modems. This message MUST use an FC field with FC_TYPE = MAC Specific Header and FC_PARM = Timing MAC Header. This MUST be followed by a Packet PDU in the format shown in Figure 6-2.

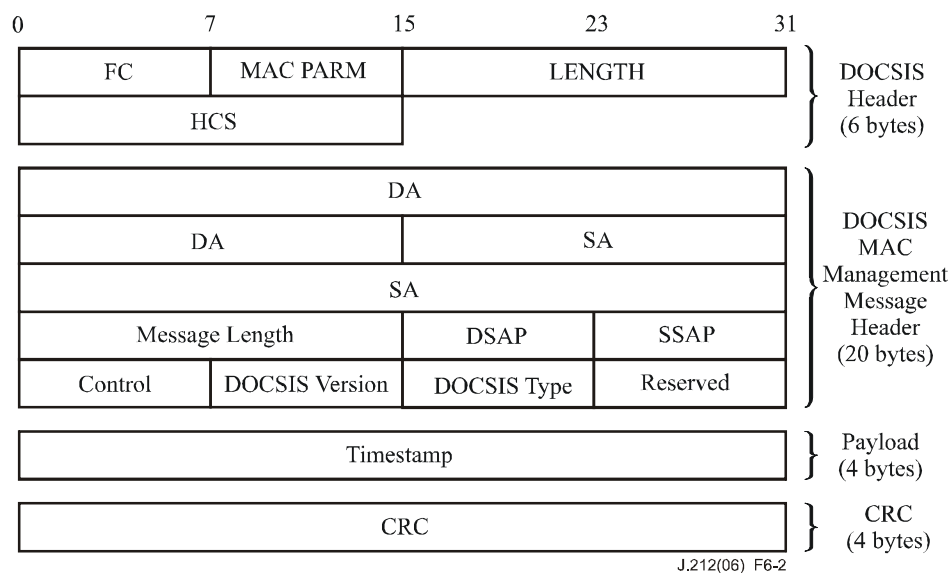


Figure 6-2/J.212 – Format of a DOCSIS SYNC MAC message

The fields MUST be as defined below:

FC, MAC PARM, LEN, HCS: Common MAC frame header with FC_PARM field to indicate a timing header – refer to J.122 for details.

Destination Address (DA): Set to the DOCSIS MAC multicast address of 01-E0-2F-00-00-01.

Source Address (SA): The MAC address of the M-CMTS Core. In PSP Mode, the EQAM learns the appropriate M-CMTS Core MAC address via explicit signalling during L2TPv3 session setup.

Msg Length: Length of the MAC message from DSAP to the end of the payload.

DSAP: The LLC null destination SAP (00) as defined by [ISO 8802-2].

SSAP: The LLC null source SAP (00) as defined by [ISO 8802-2].

Control: Unnumbered information frame (03) as defined by [ISO 8802-2].

DOCSIS Version: Set to 1.

DOCSIS Type: Set to 1 to indicate a SYNC message.

CMTS Timestamp: The count state of an incrementing 32-bit binary counter clocked with the master clock derived from [J.211].

The CMTS timestamp represents the count state at the instant that the first byte (or a fixed time offset from the first byte) of the Time Synchronization MAC Management Message is transferred from the Downstream Transmission Convergence Sublayer, to the Downstream Physical Media Dependent Sublayer, as described in [J.210].

6.1.3.2 Correction and insertion

The EQAM MUST derive a local DOCSIS timestamp from the DTI Client, specified in [J.211]. The EQAM MUST support either a 10.24 MHz master clock frequency or a 9.216 MHz master clock frequency depending on the region in which it will operate. In the D-MPT mode, the EQAM must be capable of correcting all embedded SYNC messages in the DOCSIS stream. For the DOCSIS PSP mode, the EQAM MUST be capable of inserting DOCSIS SYNC messages based upon its internal timestamp into the downstream MPEG-TS stream within the specifications in 6.1.3.3. In PSP Mode, the EQAM MUST insert the SYNC message starting at the 6th byte of the MPEG-TS frame (the fifth byte would be the MPEG pointer_field). When referencing a timebase to use for SYNC timestamp insertion or correction, the EQAM MUST utilize a timebase that is delayed by no less than 0 and no more than 100 clock cycles (approximately 10 µs) of the master clock compared to the time communicated via the DTI Client Test Port output.

This time difference between the time communicated via the DTI Client Test Port output and the time reference applied by an EQAM is expected to be essentially constant. All timing and jitter requirements that exist in this Recommendation and [J.210] still apply. The requirements here do not preclude an EQAM from taking longer than 100 clock cycles to process the DTI conveyed time, but in that case, the EQAM would need to internally adjust the applied timebase such that it is delayed between zero and 100 clock cycles from the DTI conveyed timebase.

When using the D-MPT mode, the M-CMTS Core MUST generate SYNC messages and include them in the D-MPT payload. The M-CMTS Core MUST insert the SYNC message starting at the 6th byte of the MPEG-TS frame (the fifth byte would be the MPEG pointer_field). This is intended to simplify the EQAM implementation by allowing the EQAM to check only the payload_unit_start_indicator bit and the fifth and sixth byte (which together will contain 0x00C0) of the MPEG-TS packet to locate a DOCSIS SYNC message. Note that the CMTS Timestamp in the SYNC messages generated by the M-CMTS core is not required to accurately reflect the current timestamp received via a DTI Client in the M-CMTS Core. For example, it is permissible for the M-CMTS Core to use a value of zero for the CMTS Timestamp in all SYNC messages. When using the DOCSIS PSP mode, the M-CMTS Core MUST NOT generate SYNC messages as part of the PSP payload.

6.1.3.3 Timestamp jitter

The DOCSIS timestamp jitter MUST be less than 500 ns peak-to-peak at the output of the Downstream Transmission Convergence Sublayer. This jitter is relative to an ideal Downstream Transmission Convergence Sublayer that transfers the MPEG packet data to the Downstream Physical Media Dependent Sublayer with a perfectly continuous and smooth clock at the MPEG packet data rate. Downstream Physical Media Dependent Sublayer processing MUST NOT be considered in timestamp generation and transfer to the Downstream Physical Media Dependent Sublayer.

Thus, any two timestamps N1 and N2 ($N2 > N1$) which were transferred to the Downstream Physical Media Dependent Sublayer at times T1 and T2 respectively must satisfy the following relationship:

$$|(N2 - N1)/f_{\text{CMTS}} - (T2 - T1)| < 500 \times 10^{-9}$$