IEEE Draft P802.3ah™/D1.414

Draft Amendment to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications—

Media Access Control Parameters, Physical Layers and Management Parameters for subscriber access networks

Sponsor

LAN MAN Standards Committee
of the
IEEE Computer Society

This is the text proposed by the IEEE 802.3ah Ethernet in the First Mile Task Force editors as draft D1.414 of an amendment to IEEE Std 802.3-2002. This draft combines a minimal set of extensions to the IEEE 802.3 Media Access Control (MAC) and MAC Control sublayers with a family of Physical (PHY) Layers. These Physical Layers include optical fiber and voice grade copper cable Physical Medium Dependent sublayers (PMDs) for point to point connections in subscriber access networks. This draft also introduces the concept of Ethernet Passive Optical Networks (EPONs), in which a point to multipoint (P2MP) network topology is implemented with passive optical splitters, along with optical fiber PMDs that support this topology. In addition, a mechanism for network Operations, Administration and Maintenance (OAM) is included to facilitate network operation and troubleshooting. This draft is being distributed for review and comment within the IEEE 802.3ah Ethernet in the First Mile Task Force. It represents an attempt by the Task Force editors to convert the suite of baseline presentations that have been adopted by the Task Force into text, along with the incorporation of changes agreed to at the March, 2003 Task Force meeting in Dallas, Texas. The draft has no special status, and ALL OF IT IS SUBJECT TO CHANGE. The formal expiration date of this draft is May 16, 2003.

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Introduction

(This introduction is not part of IEEE P802.3ah-2002™, Draft Amendment to IEEE Std 802.3-2002™.)

This document defines services and protocol elements that permit the exchange IEEE Std 802.3 format frames between stations in a subscriber access network.

The following is a list of participants in the IEEE 802.3 Working Group. Voting members at the time of publication are marked with an asterisk (*).

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Howard Frazier, *Chair, EFM Task Force*
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List of 802.3 WG members

The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

To be supplied by IEEE

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List of special symbols

For the benefit of those who have received this document by electronic means, what follows is a list of special symbols and operators. All special symbols and operators are taken from the "SYMBOL" font set supported on most Windows, MacIntosh, and UNIX systems. If any of these symbols or operators fail to print out correctly on your machine, the editors apologize, and hope that this table will at least help you to sort out the meaning of the resulting funny-shaped blobs and strokes.

Special symbols formed from the "SYMBOL" font set may be prepared in the following way: First, change to "SYMBOL" font. There is an entry under Format, Characters for this purpose. Then, while continuously holding down the ALT key, enter the three- or four-digit code using the numbers on your numeric keypad (the "NumLock" feature must be ON for this to work). Alternatively, cut and paste the symbols you need from this page. Those editors who are using Mac or UNIX may use window pull-down menus to insert symbol-font characters.

Special symbols and operators

Printed Character	Meaning	Frame V character code	Font
*	Boolean AND	ALT-042	Symbol
+	Boolean OR, Arithmetic addition	ALT-043	Symbol
^	Boolean XOR	^	Times
!	Boolean NOT	ALT-033	Symbol
<	Less than	ALT-060	Symbol
≤	Less than or equal to	ALT-0163	Symbol
=	Equal to	ALT-061	Symbol
≠	Not equal to	ALT-0185	Symbol
≥	Greater than or equal to	ALT-0179	Symbol
>	Greater than	ALT-062	Symbol
⇐	Assignment operator	ALT-0220	Symbol
∈	Indicates membership	ALT-0206	Symbol
∉	Indicates nonmembership	ALT-0207	Symbol
±	Plus or minus (a tolerance)	ALT-0177	Symbol
°	Degrees (as in degrees Celsius)	ALT-0176	Symbol
∑	Summation	ALT-0229	Symbol
—	Big dash (Em dash)	Ctrl-q Shft-q	Times
–	Little dash (En dash)	Ctrl-q Shft-p	Times
†	Dagger	ALT-0134	Times
‡	Double dagger	ALT-0135	Times

Changes to ANSI/IEEE Std 802.3, 2002, Clause 4

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions:

None.

Abbreviations:

None.

Issues:

Most of the modified text comes from 802.3ae-2002.

Revision History:

Draft 1.2	November 2002	First changes to this clause due to inclusion of FEC
Draft 1.3	January 2003	Changes to make ifsStretching more generic
Draft 1.414	April 2003	Used correct clause title

4. Media Access Control

4.2.3.2.2 Interframe spacing

Change the third paragraph of 4.2.3.2.2 to read:

A larger value for interframe spacing is used for dynamically adapting the nominal data rate of the MAC sublayer to SONET/SDH data rates (with packet granularity) for WAN-compatible applications of this standard. A larger value is also used when the MAC sublayer is communicating over a physical layer that uses Forward Error Correction (FEC). While in this optional mode of operation, the MAC sublayer counts the number of bits sent during a frame's transmission. After the frame's transmission has been completed, the MAC sublayer extends the minimum interframe spacing by a number of bits that is proportional to the length of the previously transmitted frame. For more details, see *CROSS REF* 4.2.7 and *CROSS REF* 4.2.8.

4.2.7.2 Transmit state variables

Modify the following "const":

ifsStretchRatio = ... ; {In bits, determines the number of bits in a frame that require ~~one octet~~ ifsStretchMultipler bits of interFrameSpacing extention, when ifsStretchMode is enabled; implementation dependent, see *CROSS REF* 4.4}

Add the following new "const"s:

ifsStretchMultiplier = ... ; {In bits, determines the number of bits of interFrameSpacing extention that are required for every ifsStretchRatio bits in a frame, when ifsStretchMode is enabled; implementation dependent, see *CROSS REF* 4.4}

ifsStretchConstant = ... ; {In bits, determines the number of bits of interFrameSpacing extention that are required for every frame, when ifsStretchMode is enabled; implementation dependent, see *CROSS REF* 4.4}

ifsStretchCarry = ... ; {Determines the desire to carry over any remainder bits in ifsStretchCount to the next waiting frame, when ifsStretchMode is enabled; implementation dependent, see *CROSS REF* 4.4}

ifsStretchIncludeIFS = ... ; {Determines the desire to include the frame's normal interFrameSpacing when calculating the interFrameSpacing extension for that frame; implementation dependent, see *CROSS REF* 4.4}

Modify the following "var":

ifsStretchSize: 0..(((maxUntaggedFrameSize + qTagPrefixSize) x 8 + headerSize + interFrameSpacing + ifsStretchRatio + ifsStretchConstant - 1) *div* ifsStretchRatio);
{In octets, a running counter that counts the integer number of octets that are to be added to the minimum interFrameSpacing, while operating in ifsStretchMode}

Modify the following assignment in the* Initiailize *procedure:

ifsStretchMode := ...; {True for operating speeds at or above 1000 Mb/s when lowering the average data rate of the MAC sublayer (with frame granularity) is desired and supported, false otherwise}

4.2.8 Frame transmission

Modify the Deference and BitTransmitter procedures:

The Deference process runs asynchronously to continuously compute the proper value for the variable deferring. In the case of half duplex burst mode, deferring remains true throughout the entire burst. Interframe spacing may be used to lower the average data rate of a MAC at operating speeds above 1000 Mb/s in the full duplex mode, when it is necessary to adapt it to the data rate of a WAN-based physical layer or at operating speeds at 1000 Mb/s in the full duplex mode, when it is necessary to adapt it to the data rate of a physical layer using Forward Error Encoding. When interframe stretching is enabled, deferring remains true throughout the entire extended interframe gap, which includes the sum of interFrameSpacing and the interframe extension as determined by the BitTransmitter:

```
process Deference;
   var realTimeCounter: integer; wasTransmitting: Boolean;
begin
   if halfDuplex then cycle{Half duplex loop}
      while not carrierSense do nothing; {Watch for carrier to appear}
      deferring := true;  {Delay start of new transmissions}
      wasTransmitting := transmitting;
      while carrierSense or transmitting do wasTransmitting := wasTransmitting or transmitting;
      if wasTransmitting then Wait(interFrameSpacingPart1) {Time out first part of interframe gap}
      else
         begin
            realTimeCounter := interFrameSpacingPart1;
            repeat
               while carrierSense do realTimeCounter := interFrameSpacingPart1;
               Wait(1);
               realTimeCounter := realTimeCounter – 1
            until (realTimeCounter = 0)
         end;
      Wait(interFrameSpacingPart2); {Time out second part of interframe gap}
      deferring := false; {Allow new transmissions to proceed}
      while frameWaiting do nothing {Allow waiting transmission, if any}
   end {Half duplex loop}
   else cycle {Full duplex loop}
      while not transmitting do nothing; {Wait for the start of a transmission}
      deferring := true; {Inhibit future transmissions}
      while transmitting do nothing; {Wait for the end of the current transmission}
      Wait(interFrameSpacing + ifsStretchConstant + (ifsStretchSize x ~~8~~ifsStretchMultiplier));
                                          {Time out entire interframegap and IFS extension}
      if not frameWaiting then {Don't roll over the remainder into the next frame}
         begin
            Wait(8);
            ifsStretchCount := 0
         end
      deferring := false {Don't inhibit transmission}
   end {Full duplex loop}
end; {Deference}
```

If the ifsStretchMode is enabled, the Deference process continues to enforce interframe spacing for an additional number of bit times, after the completion of timing the interFrameSpacing. The additional number of bit times is reflected by the variable ifsStretchSize and the constant ifsStretchMultiplier. If the variable ifsStretchCount is less than ifsStretchRatio and the next frame is ready for transmission (variable frameWaiting is true), the Deference process enforces interframe spacing only for the integer number of octets, as indicated by ifsStretchSize and ifsStretchMultiplier, and saves ifsStretchCount for the next frame's transmission. If the next frame is not ready for transmission (variable frameWaiting is false), then the Deference process initializes the ifsStretchCount variable to zero.

The BitTransmitter process runs asynchronously, transmitting bits at a rate determined by the Physical Layer's TransmitBit operation:

```
process BitTransmitter;
begin
    cycle {Outer loop}
        if transmitting then
            begin {Inner loop}
                extendError := false;
                if ifsStretchMode then {Calculate the counter values}
                    begin
                        ifsStretchSize := (ifsStretchCount + headerSize + frameSize +
                                                    (ifsStretchIncludeIFS x interFrameSpacing)) div ifsStretchRatio;
                                                        {Extension of the interframe spacing};
                        ifsStretchCount := (ifsStretchCount + headerSize + frameSize +
                                                    (ifsStretchIncludeIFS x interFrameSpacing)) mod ifsStretchRatio
                                                        {Remainder to carry over into the next frame's transmission};
                        if ifsStretchCount and not ifsStretchCarry then
                            begin
                                ifsStretchSize := ifsStretchSize + ifsStretchMultiplier;
                                ifsStretchCount := 0
                            end
                    end;
                PhysicalSignalEncap;  {Send preamble and start of frame delimiter}
                while transmitting do
                    begin
                        if (currentTransmitBit > lastTransmitBit) then TransmitBit(extensionBit)
                        else if extendError then TransmitBit(extensionErrorBit) {Jam in extension}
                        else TransmitBit(outgoingFrame[currentTransmitBit]);
                        if newCollision then StartJam else NextBit
                    end;
                if bursting then
                    begin
                        InterFrameSignal;
                        if extendError then
                            if transmitting then transmitting := false
                                                {TransmitFrame may have been called during InterFrameSignal}
                            else IncLargeCounter(lateCollision);
                                                {Count late collisions which were missed by TransmitLinkMgmt}
                        bursting := bursting and (frameWaiting or transmitting)
                    end
            end {Inner loop}
    end {Outer loop}
end; {BitTransmitter}
```

4.4.2 Allowable implementations

Add the following new table:

The following parameter values shall be used for the allowed rate adaptation implementations:

Parameters	Values		
	Typical	WAN	FEC
ifsStretchConstant	0 bits	0 bits	112 bits
ifsStretchCarry	0	1	0
ifsStretchIncludeIFS	0	1	0
ifsStretchMultiplier	not applicable	8 bits	128 bits
ifsStretchRatio	not applicable	104 bits	1912 bits

Changes to ANSI/IEEE Std 802.3, 2002, Clause 22

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions:

None.

Abbreviations:

None.

Issues:

Clause 22 has been extended by P802.3af - DTE Power via MDI. Modifications described in this clause assume the extensions of P802.3af will be approved.

Revision History:

Draft 1.1	October 2002	Added register bit 0.1 & 1.7 descriptions per comment #420. Added register bits 13.15:0 per comments #1002 & 1003.
Draft 1.2	November 2002	Cleaned up tabs in this section Replace "OAM Enable" with "Unidirectional OAM Enable" in Table 22-7 & 22.2.4.1.12 Correct spelling "alue" to "value" in 22.2.4.1.12 Correct table numbering in 22.2.4.2 Replace numerous instances of "MII" with "media independent interface" in 22.2.4 Replace "OAM Ability" with "Unidirectional OAM Ability" in Table 22-8 & 22.2.4.2.8 Move Coding Violation Counter to clause 45 to make room for new C45 access regs Define regs 13 & 14 as new C45 access regs
Draft 1.3	January 2003	Changed $420 to #420 in this section Change "Clause 45 Access" to "MMD Access" for register names Only set 0.1 when OAM exists and is enabled Corrected numbering of MMD Access registers from 22.2.4.1.11/12 to 22.2.4.3.11/12 then moved these subclauses to the appropriate place in this clause. This was found when creating the PICs entries and was not the result of a comment against D1.2 Clean up numbering sources for cleaner editorial changes
Draft 1.414	April 2003	Replace "shall" with "should" for setting 0.1 when OAM sublayer exists and is enabled Remove associated PICS entry MF41 and editors' note below table Correct reference in PICS table from 22.2.4.3.12 to 22.2.4.1.12

22. Reconcilation Sublayer (RS) and Media Independent Interface (MII)

22.2.4 Management functions

Add a row for Register 13 and change row for Register 14 in Table 22-6:

Table 22–6—MII management register set

Register Address	Register Name	Basic / Extended MII	Basic / Extended GMII
10	MASTER-SLAVE Status Register	E	E
11	PSE Control Register	E	E
12	PSE/PD Status Register	E	E
13	MMD Access Control Register	E	E
14	MMD Access Address Data Register	E	E

D1.0, Comment #420 resolution was to open Clauses 28 & 37 so that Register bit 6.5 could be described. The editor has taken it upon himself to move this register bit from 6.5 to 0.1. This was done because it only requires opening 1 clause rather than 2. It also puts OAM Enable in the same clause and register as Auto-Negotiation Enable. This makes it easier to describe in just one place that these 2 bits should never be set at the same time. In addition to moving this register bit from 6.5 to 0.1, I've added 1.7 as the ability for a PHY to support the OAM Enable function.

22.2.4.1 Control register (Register 0)

Change the fourth and last rows of Table 22-7 and add 2 new rows below that. Their contents are:

Table 22–7—Control register bit definitions

Bit(s)	Name	Description	R/W
0.12	Auto-Negotiation Enable[c]	1 = Enable Auto-Negotiation Process 0 = Disable Auto-Negotiation Process	R/W
0.5:2	Reserved	Write as 0, ignore on Read	R/W
0.1	Unidirectional OAM Enable[c]	1 = Enable transmit from media independent interface regardless of link_status 0 = Enable transmit from media independent interface only when link_status=TRUE	R/W
0.0	Reserved	Write as 0, ignore on Read	R/W

Add an additional footnote under the table:

[c]Auto-Negotiation Enable and Unidirectional OAM Enable bits should never be set at the same time.

In 22.2.4.1.11, replace

Bits 0.5:0

with

Bits 0.5:2 and 0.0

Add subclause:

22.2.4.1.12 Unidirectional OAM Enable

The ability to encode and transmit data from the media independent interface regardless of the value of link_status shall be enabled by setting bit 0.1 to a logic one. If a PHY reports via bit 1.7 that it lacks the ability to encode and transmit data from the media independent interface regardless of the value of link_status, the PHY shall return a value of zero in bit 0.1. If a PHY reports via bit 1.7 that it lacks the ability to encode and transmit data from the media independent interface regardless of the value of link_status, bit 0.1 should always be written as zero, and any attempt to write a one to bit 0.1 shall be ignored.

The default value of bit 0.1 is zero. Bits 0.1 and 0.12 should never have the value one simultaneously. Doing so may provide unpredictable results. Bit 0.1 should only be set when an OAM sublayer entity exists and is enabled.

22.2.4.2 Status register (Register 1)

Change the ninth row of Table 22-8. The new content is:

Table 22–8—Control register bit definitions

Bit(s)	Name	Description	R/W
1.7	Unidirectional OAM Ability	1 = PHY is able to transmit from media independent interface regardless of link_status 0 = PHY is able to transmit from media independent interface only when link_status=TRUE	RO

Replace 22.2.4.2.8

22.2.4.2.8 Unidirectional OAM Ability

When read as a logic one, bit 1.7 indicates that the PHY has the ability to encode and transmit data from the media independent interface regardless of the value of link_status. When read as a logic zero, bit 1.7 indicates the PHY lacks the ability to encode and transmit data from the media independent interface regardless of the value of link_status.

Add the following new subclause after subclause 22.2.4.3.10, renumber current subclause 22.2.4.3.11 to 22.2.4.3.13. Renumber current tables after the newly inserted tables.

22.2.4.3.11 MMD Access Control register (Register 13)

The assignment of bits in the MMD Access Control register is shown in Table 22–9. The MMD Access Control register is used in conjunction with the MMD Access Address Data register (register 14) to provide access to the MMD address space using the interface and mechanisms defined in 22.2.4.

Table 22–9—MMD Access Control register bit definitions

Bit(s)	Name	Description	R/W
13.15:14	Function	00 = Address 01 = Data, no post increment 10 = Data, post increment on reads and writes 11 = Data, post increment on writes only	R/W
13.13:5	Reserved	Write as 0, ignore on Read	R/W
13.4:0	DEVAD	Device Address	R/W

The DEVAD field directs any accesses of register 14 to the appropriate MDIO Manageable Device (MMD) as described in *CROSS REF* 45.1.2. Each MMD that can be accessed using this mechanism maintains its own individual address register as described in *CROSS REF* 45.3. Both the DEVAD field of register 13 and the MMD's address register direct the data accesses to register 14 to the appropriate registers in the MMD.

The Function field can be set to any of 4 values:

— When set to 00, accesses to register 14 access the MMD's individual address register. This address register should always be initialized before attempting any accesses to other MMD registers.
— When set to 01, accesses to register 14 access the register within the MMD selected by the value in the MMD's address register.
— When set to 10, accesses to register 14 access the register within the MMD selected by the value in the MMD's address register. After that access is complete, for both read and write acesses, the value in the MMD's address field is incremented.
— When set to 11, accesses to register 14 access the register within the MMD selected by the value in the MMD's address register. After that access is complete, for write accesses only, the value in the MMD's address field is incremented. For read accesses, the value in the MMD's address field is not modified.

22.2.4.3.12 MMD Access Address Data register (Register 14)

The assignment of bits in the MMD Access Address Data register is shown in Table 22–10. The MMD Access Address Data register is used in conjunction with the MMD Access Control register (register 13) to provide access to the MMD address space using the interface and mechanisms defined in 22.2.4. Accesses to this register are controlled by the value of the fields in register 13 and the contents of the MMD's individual address field as described in 22.2.4.3.11.

Table 22–10—MMD Access Address Data register bit definitions

Bit(s)	Name	Description	R/W
14.15:0	Address Data	If 13.15:14 = 00, MMD DEVAD's address register. Otherwise, MMD DEVAD's data register as indicated by the contents of its address register	R/W

Modify 22.7.3.4 to insert new PICS entrys after MF37 and renumber all remaining entries:

Item	Feature	Subclause	Status	Support	Value/Comment
MF38	Unidirectional OAM Enable	22.2.4.1.12	M		By setting 0.1 = 1
MF39	PHY without unidirectional OAM ability returns value of 0	22.2.4.1.12	M		Yes (if 1.7=0, then 0.1=0)
MF40	PHY without unidirectional OAM ability ignores writes to enable bit	22.2.4.1.12	M		Yes (if 1.7=0, 0.1 always = 0 and cannot be changed)

Changes to ANSI/IEEE Std 802.3, 2002, Clause 24

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or <u>underscore</u> (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions:

None.

Abbreviations:

None.

Issues:

a) Need to add mr_oam_enable to MDIO register bit 6.5(?) in Clause 22. - Closed - Added bit 0.1 in Clause 22.
b) Need to explain to the user when mr_oam_enable is set, mr_autoneg_enable should be clear. - Closed - Added in Clause 22.

Revision History:

Draft 0.91	August 2002	Initial draft for IEEE P802.3ah Editors' review.
Draft 1.0	August 2002	Reduce content of file to changes only.
Draft 1.1	October 2002	Added Coding Violation Counter per comment #1002. Closed all issues (above).
Draft 1.2	November 2002	Cleaned up tabs in this section Remove "bits" in 24.2.2.1.7 Moved 24.2.2.1.7 ahead of 24.2.3.2 Change "OAM capability" to "unidirectional OAM Capability" in 24.2.3.2 Change "mr_oam_enable" to "mr_unidirectional_oam_enable" in 24.2.3.2 Remove "bit" in 24.2.3.2 Modified formatting to align text with figures Use correct assignment symbol in Figures 24-8 & 24-16 Use correct not equal symbol in Figure 24-8
Draft 1.3	January 2003	Change "mr_oam_enable" to "mr_unidirectional_oam_enable" in all other places Change description of effect of setting mr_unidirectional_oam_enable in 24.2.4.2 from "allowing transmission of frames" to "enables the ability to transmit OAMPDUs" Clean up numbering sources for cleaner editorial changes
Draft 1.414	April 2003	Get new reference to register bits for coding violation counter

24. Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X

24.2.2.1.7 PCS Management Counter

The following counter applies to PCS management. If an MDIO interface is provided (see *CROSS REF* Clause 22), it is accessed via that interface. If not, it is recommended that an equivalent access be provided. This counter is reset to zero upon read or upon reset of the PCS. When it reaches all ones, it stops counting. Its purpose is to help monitor the quality of the link.

coding_violation_counter:

16-bit counter. When the receiver is in normal mode, coding_violation_counter counts once for each invalid code-group received, other than the /H/ code-group. This counter is reflected in *CROSS REF* 45.2.1.

24.2.3.2 Variables

Insert new variable in proper alphabetical location:

mr_unidirectional_oam_enable

Controls the enabling and disabling of unidirectional OAM capability. This bit reflects the value in MDIO register 0.1.

Values: FALSE; Unidirectional OAM capability is not enabled
TRUE; Unidirectional OAM capability is enabled

Insert new subclause:

24.2.4.2 Transmit

Modify the second paragraph as follows:

Collision detection is implemented by noting the occurrence of carrier receptions during transmissions, following the model of 10BASE-T. The indication of link_status ≠ OK by the ~~PMA at any time~~ PMA, when mr_unidirectional_oam_enable = FALSE, causes an immediate transition to the IDLE state and supersedes any other Transmit process operations.

Insert new paragraph after the second paragraph:

When mr_unidirectional_oam_enable = TRUE, the Transmit process ignores the value of link_status. This enables the ability to transmit OAMPDUs when link_status ≠ OK.

Add new term at the top of figure 24-8:

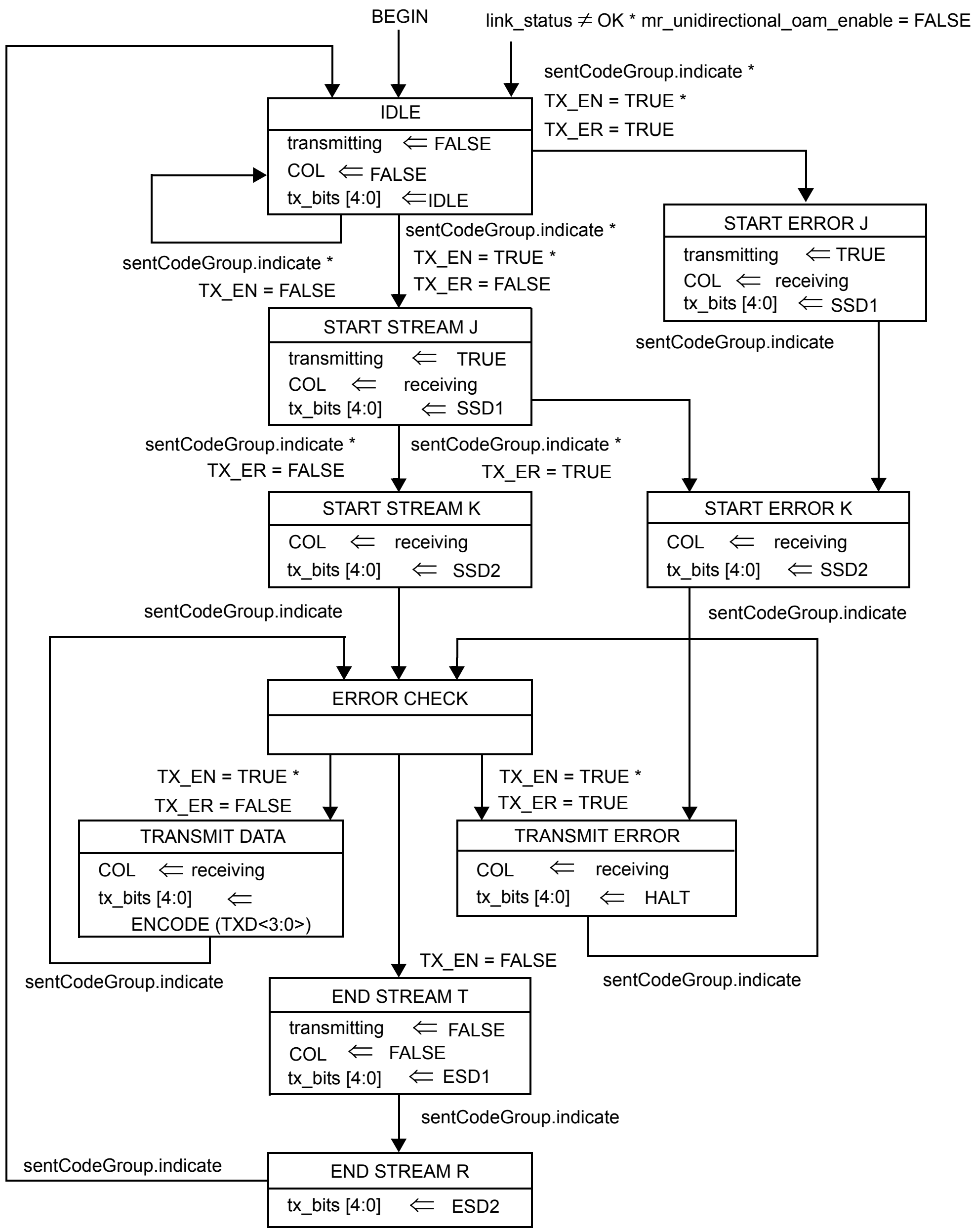

Figure 24–8—Transmit state diagram

24.3.4.5 Far-End Fault Generate

Modify the first paragraph as follows:

Far-End Fault Generate simply passes tx_code-bits to the TX process when signal_status=ON or when mr_unidirectional_oam_enable=TRUE. When signal_status=OFF and mr_unidirectional_oam_enable=FALSE, it repetitively generates each cycle of the Far-End Fault Indication until signal_status is reasserted.

Add new terms to figure 24-16:

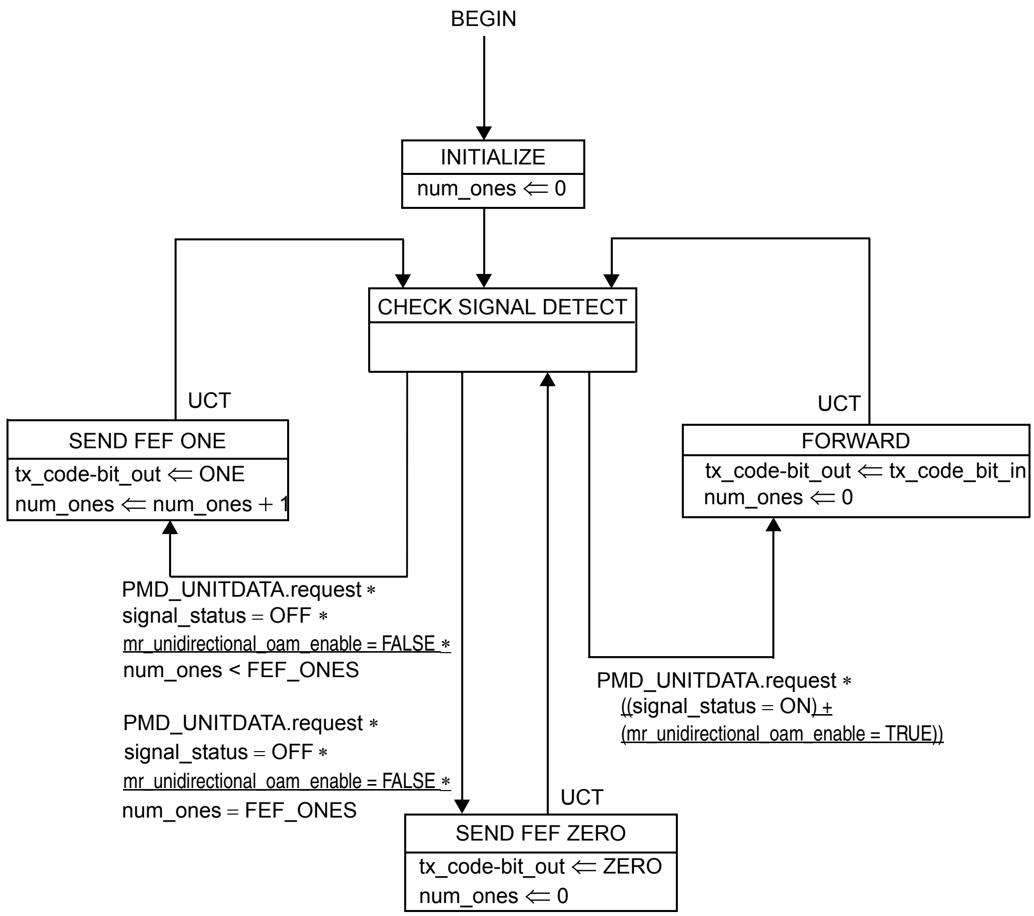

Figure 24–16—Far-End Fault Generate state diagram

Changes to ANSI/IEEE Std 802.3-2002, Clause 30

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3-2002 as modified by IEEE Std 802.3ae-2002 10Gb/s Ethernet and Draft 4.2 of IEEE P802.3af, DTE Power via MDI. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of IEEE P802.3ah.

Editing instructions are shown in bold italic. Three editing instructions are used: change, delete, and insert. *Change* is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions:

None.

Abbreviations:

None.

Revision History:

Draft 0.91, July 16, 2002	Initial discussion draft.
Draft 0.92, July 22, 2002	Add EPON Mux and emulation objects. Add examples for discussion.
Draft 0.93, Jul 29, 2002	Change EPON layering to have Aggregation and OAM above OMPMuxing. Add other suggested attributes.
Draft 0.94, Aug 14, 2002	OAM D0.9 internal review comment related changes. Added 2PASS-TBD long haul Copper options Changed 10PASS-TA/TB to 10PASS-TBD as the suffixes have yet to be finalized. Remove headings related to oCopper as these are still Work in progress for the Copper sub Task Force.
Draft 1.0, Aug 15, 2002	Updated header, Framemaker 7.0 conversion.
Draft 1.1, Oct. 10, 2002	D1.0 Task Force review comments.
Draft 1.2, Nov. 21, 2002	D1.1 Task Force review comments.
Draft 1.3, Jan. 20, 2003	D1.2 Task Force review comments.
Draft 1.414, Mar. 31, 2003	D1.3 Task Force review comments.

30. 10 Mb/s, 100 Mb/s, 1000 Mb/s and 10 Gb/s Management

30.1 Overview

Change the first paragraph of this subclause as follows:

This clause provides the Layer Management specification for DTEs, repeaters, and MAUs based on the CSMA/CD access method. The clause is produced from the ISO framework additions to Clause 5, Layer Management; Clause 19, Repeater Management; and Clause 20, MAU Management. It incorporates additions to the objects, attributes, and behaviors to support 100 Mb/s, 1000 Mb/s and 10 Gb/s, full duplex operation, MAC Control, Link Aggregation, ~~and~~ DTE Power via MDI and subscriber access networks.

30.1.1 Scope

Change the first paragraph of this subclause as follows:

This clause includes selections from Clauses 5, 19, and 20. It is intended to be an entirely equivalent specification for the management of 10 Mb/s DTEs, 10 Mb/s baseband repeater units, and 10 Mb/s integrated MAUs. It also includes the additions for management of MAC Control, DTEs and repeaters at speeds greater than 10 Mb/s, embedded MAUs/PHYs, ~~and~~ DTE Power via MDI and subscriber access networks. Implementations of management for DTEs, repeater units, and embedded MAUs should follow the requirements of this clause (e.g., a 10 Mb/s implementation should incorporate the attributes to indicate that it is not capable of 100 or 1000 Mb/s operation~~,~~; half duplex DTE should incorporate the attributes to indicate that it is not capable of full duplex operation, etc.).

30.2.2.1 Text description of managed objects

Change the subclause as follows:

In case of conflict, the formal behavior definitions in 30.3, 30.4, 30.5, 30.6, and 30.7 take precedence over the text descriptions in this subclause.

oAggregator	If implemented, oAggregator is the top-most managed object class of the DTE ~~portion of the~~ containment trees shown in Figure 30–3 and 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard. The oAggregator managed object class provides the management controls necessary to allow an instance of an Aggregator to be managed.
oAggregationPort	If oAggregator is implemented, oAggregationPort is contained within oAggregator. An instance of this managed object class is present for each Aggregation Port that is part of the aggregation represented by the oAggregator instance. This managed object class provides the basic management controls necessary to allow an instance of an Aggregation Port to be managed, for the purposes of Link Aggregation.
oAggPortStats	If oAggregator is implemented, a single instance of oAggPortStats may be contained within oAggregationPort. This managed object class provides optional additional statistics related to LACP and Marker protocol activity on an instance of an Aggregation Port that is involved in Link Aggregation.
oAggPortDebugInformation	

If oAggregator is implemented, a single instance of oAggPortDebugInformation may be contained within oAggregationPort. This managed object class provides optional additional information that can assist with debugging and fault finding in Systems that support Link Aggregation.

oOAM If implemented, and if oAggregator is implemented, oOAM is contained within oAggregator. An instance of this managed object class is present for each Aggregation Port that is part of the aggregation represented by the oAggregator instance. Otherwise, if implemented, oOAM becomes the top-most managed object class of the DTE containment trees shown in Figure 30–3 and 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard.

oMACControlEntity If implemented, and if oOAM is implemented, a single instance of oMACControlEntity is contained within oOAM. Otherwise, if implemented, and if oAggregator is implemented, oMACControlEntity is contained within oAggregator. Otherwise, if implemented, oMACControlEntity becomes the top-most managed object class of the DTE ~~portion of the~~ containment trees shown in Figure 30–3 and 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard.

oMACControlFunctionEntity
Contained within oMACControlEntity. Each function defined and implemented within the MAC Control sublayer has an associated oMACControlFunctionEntity for the purpose of managing that function.

oMACEntity If oMACControlEntity is implemented, oMACEntity is contained within oMACControlEntity. Otherwise, if oOAM is implemented, oMACEntity is contained within oOAM. Otherwise, if oAggregator is implemented, oMACEntity is contained within oAggregator. Otherwise, oMACEntity becomes the top-most managed object class of the DTE ~~portion of the~~ containment trees shown in Figure 30–3 and 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard.

oOMPEmulation If implemented, oOMPEmulation is contained within oMACEntity. The oOMPEmulation managed object class provides the management controls necessary to allow an instance of an OMPEmulation sublayer to be managed.

oPHYEntity If oOMPEmulation is implemented, oPHYEntity is contained within oOMPEmulation. Otherwise oPHYEntity is c~~C~~ontained within oMACEntity. Many instances of oPHYEntity may coexist within one instance of oMACEntity; however, only one PHY may be active for data transfer to and from the MAC at any one time. oPHYEntity is the managed object that contains the MAU managed object in a DTE.

oRepeater The top-most managed object class of the repeater ~~portion of the~~ containment trees shown in Figure 30–5~~Figure30-3~~. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this standard.

oRepeaterMonitor A managed object class called out by IEEE Std 802.1F-1993. See 30.1.2, oEWMAMetricMonitor.

oGroup The group managed object class is a view of a collection of repeater ports.

oRepeaterPort The repeater port managed object class provides a view of the functional link between the data transfer service and a single PMA. The attributes associated with repeater port deal with the monitoring of traffic being handled by the repeater from the port and control of the operation of the port. The Port Enable/Disable function as reported by portAdminState is preserved across events involving loss of power. The oRepeaterPort managed object contains the MAU managed object in a repeater set.

NOTE—Attachment to nonstandard PMAs is outside the scope of this standard.

oMAU The managed object of that portion of the containment trees shown in Figure 30–3, 30–4 and 30–5. The attributes, notifications, and actions defined in this subclause are contained within the MAU managed object. Neither counter values nor the value of MAUAdminState is required to be preserved across events involving the loss of power.

oAutoNegotiation The managed object of that portion of the containment trees shown in Figure 30–3, 30–4 and 30–5. The attributes, notifications, and actions defined in this subclause are contained within the MAU managed object.

oWIS The managed object of that portion of the containment trees shown in Figure 30–3 and 30–4. The attributes defined in this subclause are contained within the oMAU managed object.

oMidSpan The top-most managed object class of the Mid-Span PSE containment tree shown in Figure 30–6. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this standard.

oMidSpanGroup The MidSpanGroup managed object class is a view of a collection of PSEs.

oPSE The managed object of that portion of the containment trees shown in Figure 30–3, 30–4 and 30–6. The attributes and actions defined in this subclause are contained within the oPSE managed object.

oPD The managed object of that portion of the containment trees shown in Figure 30–3 and 30–4. The attributes and actions defined in this subclause are contained within the oPD managed object.

oResourceTypeID A managed object class called out by IEEE Std 802.1F-1993. It is used within this clause to identify manufacturer, product, and revision of managed components that implement functions and interfaces defined within IEEE 802.3. The Clause 22 MII or Clause 35 GMII specifies two registers to carry PHY Identifier (22.2.4.3.1), which provides succinct information sufficient to support oResourceTypeID.

30.1.4 Management model

Change the second last paragraph of this subclause as follows:

The above items are defined in 30.3 through 30.13~~, 30.4, 30.5, 30.6, 30.7, 30.8, 30.9 and 30.10~~ of this clause in terms of the template requirements of ISO/IEC 10165-4: 1991.

30.2.3 Containment

Change the first paragraph of this subclause as follows:

A containment relationship is a structuring relationship for managed objects in which the existence of a managed object is dependent on the existence of a containing managed object. The contained managed object is said to be the subordinate managed object, and the containing managed object the superior managed object. The containment relationship is used for naming managed objects. The local containment relationships among object classes are depicted in the entity relationship diagrams, Figure 30–3, Figure 30–4, Figure 30–5 and Figure 30–6. These figures show the names of the object classes and whether a particular containment relationship is one-to-one, ~~or~~ one-to-many or many-to-one. For further requirements on this topic, see IEEE Std 802.1F-1993.

Change Figures 30-3 as follows:

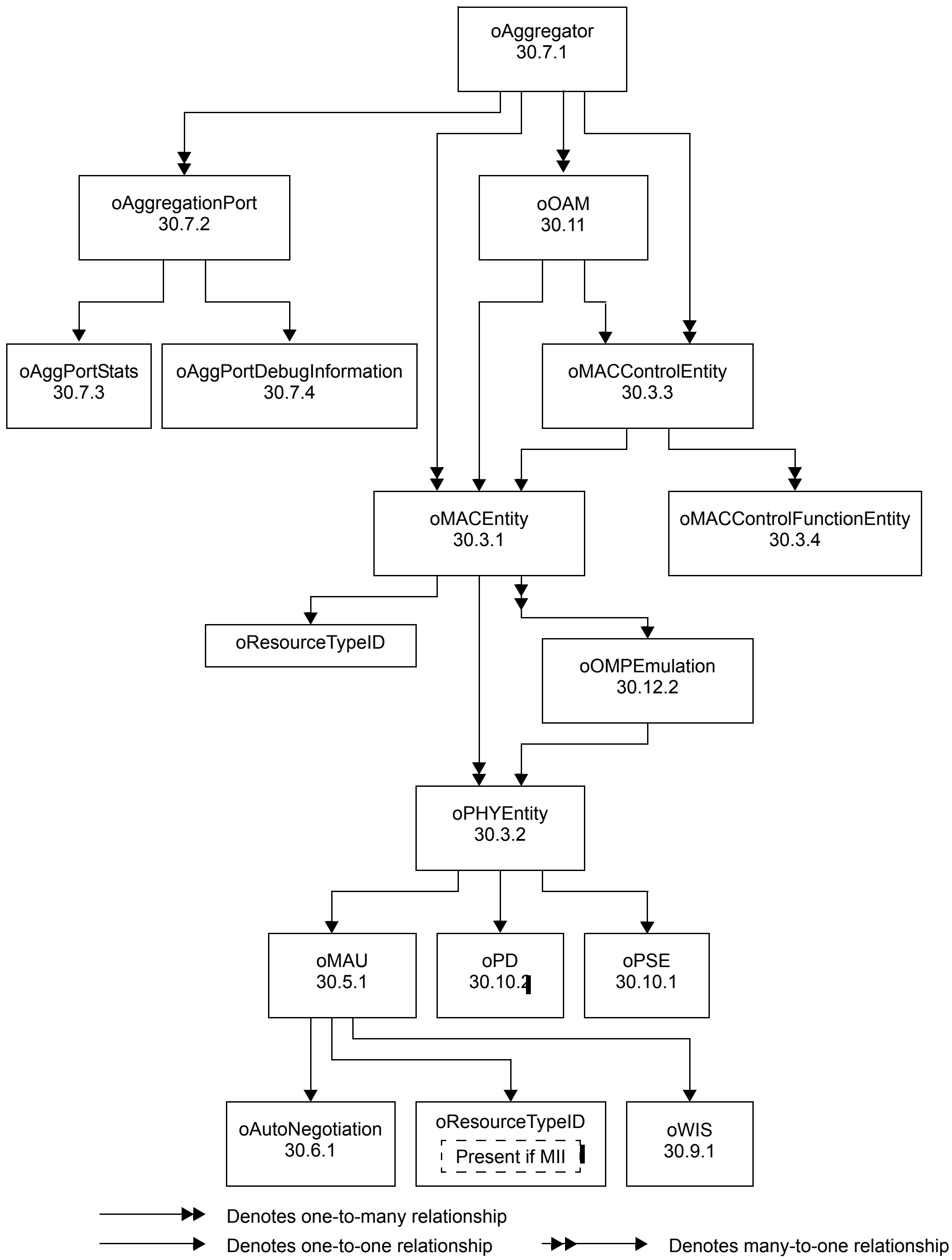

Figure 30–3—OMP DTE System entity relationship diagram

Insert new Figure 30-4 as follows.

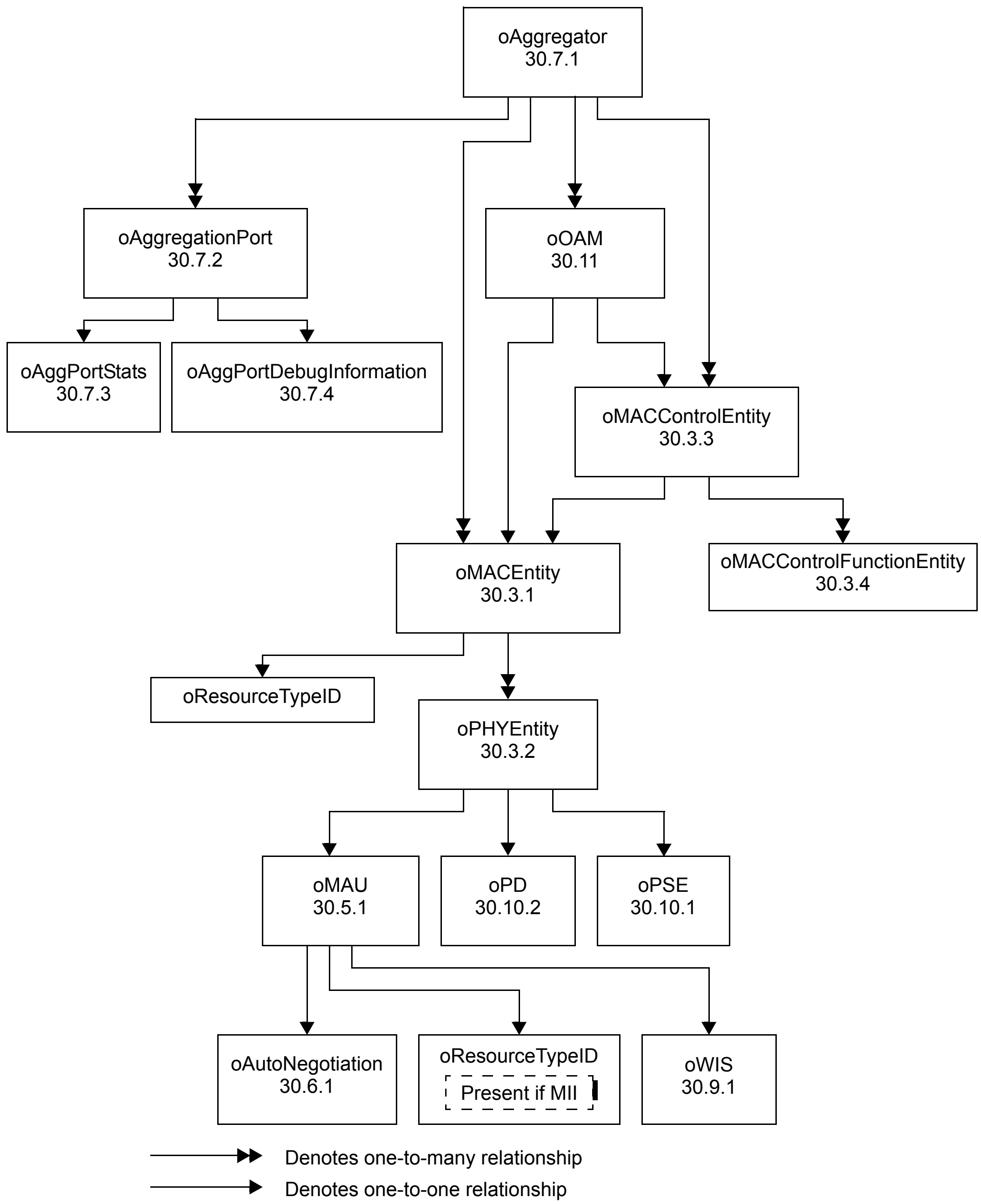

Figure 30–4—DTE System entity relationship diagram

Insert new Figure 30-5 as follows. Renumber existing Figures as required.

Editors' Notes: *To be removed prior to final publication.* Finally had to split the Repeater and DTE Entity relationship diagrams. DTE Power has also added a Mid-Span PSE entity relationship diagram.

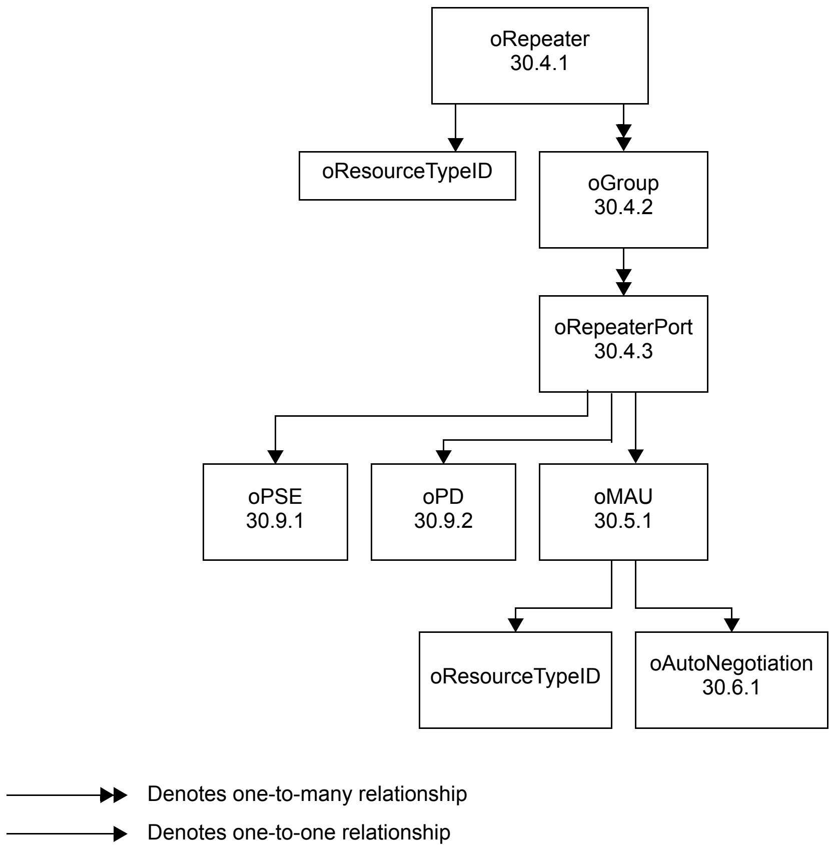

Figure 30–5—Repeater entity relationship diagram

30.2.5 Capabilities

Change the first paragraph of this subclause as follows:

This standard makes use of the concept of *packages* as defined in ISO/IEC 10165-4: 1992 as a means of grouping behaviour, attributes, actions, and notifications within a managed object class definition. Packages may either be mandatory, or be conditional, that is to say, present if a given condition is true. Within this standard *capabilities* are defined, each of which corresponds to a set of packages, which are components of a number of managed object class definitions and which share the same condition for presence. Implementation of the appropriate basic and mandatory packages is the minimum requirement for claiming conformance to IEEE 802.3 Management. Implementation of an entire optional capability is required in order to claim conformance to that capability. The capabilities and packages for IEEE 802.3 Management are specified in Tables 30–1, 30–2, ~~and~~ 30–3 and 30–4.

30.3.1.1.20 aFramesWithExcessiveDeferral

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 412 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that deferred for an excessive period of time. This counter may only be incremented once per LLC transmission. This counter is incremented when the excessDefer flag is set. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in any mode other than half duplex~~full duplex~~ mode.;

30.3.1.1.31 aMACCapabilities

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

half duplex	Capable of operating in half duplex mode
simu half duplex	Capable of operating in half duplex mode with simultaneous receive and transmit
full duplex	Capable of operating in full duplex mode

BEHAVIOUR DEFINED AS:

This indicates the capabilities of the MAC.;

Insert this following text immediately following* 30.3.1.1.34 aRateControlStatus*:

30.3.1.1.32 aIfsStretchConstant

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET operation returns the current value of ifsStretchConstant (see *CROSS REF* 4.2.7.2) of the MAC sublayer. A SET operation changes the ifsStretchConstant to the indicated value. A SET operation shall have no effect on a device whose ifsStretchConstant cannot be changed through management.

30.3.1.1.33 aIfsStretchMultiplier

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET operation returns the current value of ifsStretchMultiplier (see *CROSS REF* 4.2.7.2) of the MAC sublayer. A SET operation changes the ifsStretchMultiplier to the indicated value. A SET operation shall have no effect on a device whose ifsStretchMultiplier cannot be changed through management.

30.3.1.1.34 aIfsStretchCarry

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A GET operation returns the current value of ifsStretchCarry (see *CROSS REF* 4.2.7.2) of the MAC sublayer. A SET operation changes the ifsStretchCarry to the indicated value. A SET operation shall have no effect on a device whose ifsStretchCarry cannot be changed through management.

30.3.1.1.35 aIfsStretchIncludeIFS

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A GET operation returns the current value of ifsStretchIncludeIFS (see *CROSS REF* 4.2.7.2) of the MAC sublayer. A SET operation changes the ifsStretchIncludeIFS to the indicated value. A SET operation shall have no effect on a device whose ifsStretchIncludeIFS cannot be changed through management.

30.3.2.1.2 aPhyType

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:

other	Undefined
unknown	Initializing, true state or type not yet known
none	MII present and nothing connected
<u>2BASE-TL</u>	<u>Clause 61 0.5Mb/s to 3 Mb/s TC-PAM</u>
10 Mb/s	Clause 7 10 Mb/s Manchester
<u>10PASS-TS</u>	<u>Clause 61 TBD</u>
100BASE-T4	Clause 23 100 Mb/s 8B/6T
100BASE-X	Clause 24 100 Mb/s 4B/5B
100BASE-T2	Clause 32 100 Mb/s PAM5X5
1000BASE-X	Clause 36 1000 Mb/s 8B/10B
1000BASE-T	Clause 40 1000 Mb/s 4D-PAM5
10GBASE-X	Clause 48 10 Gb/s 4 lane 8B/10B
10GBASE-R	Clause 49 10 Gb/s 64B/66B
10GBASE-W	Clause 49 10 Gb/s 64B/66B and Clause 50 WIS

BEHAVIOUR DEFINED AS:
A read-only value that identifies the PHY type. The enumeration of the type is such that the value matches the clause number of this International Standard that specifies the particular PHY. The value of this attribute maps to the value of aMAUType. The enumeration “none” can only occur in a standard implementation where an MII exists and there is nothing connected. However, the

attribute aMIIDetect should be used to determine whether an MII exists or not.;

> ***Editors' Notes:*** *To be removed prior to final publication.*
> 1. This attribute will need updated when the Copper PHYs have been finalized.

30.3.2.1.3 aPhyTypeList

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

other	Undefined
unknown	Initializing, true state or type not yet known
none	MII present and nothing connected
<u>2BASE-TL</u>	<u>Clause 61 0.5Mb/s to 3 Mb/s TC-PAM</u>
10 Mb/s	Clause 7 10 Mb/s Manchester
<u>10PASS-TS</u>	<u>Clause 61 TBD</u>
100BASE-T4	Clause 23 100 Mb/s 8B/6T
100BASE-X	Clause 24 100 Mb/s 4B/5B
100BASE-T2	Clause 32 100 Mb/s PAM5X5
1000BASE-X	Clause 36 1000 Mb/s 8B/10B
1000BASE-T	Clause 40 1000 Mb/s 4D-PAM5
10GBASE-X	Clause 48 10 Gb/s 4 lane 8B/10B
10GBASE-R	Clause 49 10 Gb/s 64B/66B
10GBASE-W	Clause 49 10 Gb/s 64B/66B and Clause 50 WIS

BEHAVIOUR DEFINED AS:

A read-only list of the possible types that the PHY could be, identifying the ability of the PHY. If Clause 28 or Clause 37, Auto-Negotiation, is present, then this attribute will map to the local technology ability or advertised ability of the local device.

NOTE—At 10 Gb/s the ability of the PMD must be taken into account when reporting the possible types that the PHY could be.;

> ***Editors' Notes:*** *To be removed prior to final publication.*
> 1. This attribute will need updated when the all of the PHYs have been finalized.

30.3.2.1.5 aSymbolErrorDuringCarrier

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 160 000 counts per second for 100 Mb/s implementations.

BEHAVIOUR DEFINED AS:

For 100 Mb/s operation it is a count of the number of times when valid carrier was present and there was at least one occurrence of an invalid data symbol (see 23.2.1.4, 24.2.2.1.6, and 32.3.4.1).
For half duplex operation at 1000 Mb/s, it is a count of the number of times the receiving media is non-idle (a carrier event) for a period of time equal to or greater than slotTime (see 4.2.4), and during which there was at least one occurrence of an event that causes the PHY to indicate "Data reception error" or "Carrier Extend Error" on the GMII (see Table 35–2).

For full duplex operation at 1000 Mb/s, it is a count of the number of times the receiving media is non-idle (a carrier event) for a period of time equal to or greater than minFrameSize, and during which there was at least one occurrence of an event that causes the PHY to indicate “Data reception error” on the GMII (see Table 35–2).

For operation at 10 Gb/s, it is a count of the number of times the receiving media is non-idle (the time between the Start of Packet Delimiter and the End of Packet Delimiter as defined by 46.2.5) for a period of time equal to or greater than minFrameSize, and during which there was at least one occurrence of an event that causes the PHY to indicate “Receive Error” on the XGMII (see Table 46-3).

At all speeds this counter shall be incremented only once per valid CarrierEvent and if a collision is present this counter shall not increment.;

> ***Editors' Notes:*** *To be removed prior to final publication.*
> 1. This attribute will probably needs it behaviour updated due to at least one of the new PHYs.

30.3.3.2 aMACControlFunctionsSupported

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

PAUSE	PAUSE command implemented
GATE	MPCP GATE message implemented (see *CROSS REF* 64.4.2)
REPORT	MPCP REPORT message implemented (see *CROSS REF* 64.4.3)
REG_REQ	MPCP REGISTER_REQ message implemented (see *CROSS REF* 64.4.4)
REGISTER	MPCP REGISTER message implemented (see *CROSS REF* 64.4.5)
REG_ACK	MPCP REGISTER_ACK message implemented (see *CROSS REF* 64.4.6)

BEHAVIOUR DEFINED AS:

A read-write list of the possible MAC Control functions implemented within the device. Each function implemented will have an associated MAC Control Function Entity object class. ~~Currently, the only function defined is the PAUSE command.~~;

30.5.1.1.2 aMAUType

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

A GET-SET ENUMERATION that meets the requirements of the following description:

global	undefined
other	See 30.2.5
unknown	Initializing, true state or type not yet known
AUI	no internal MAU, view from AUI
2BASE-TL	Voice grade UTP PHY as specified in Clause 61 and 63
10BASE5	Thick coax MAU as specified in Clause 8
FOIRL	FOIRL MAU as specified in 9.9
10BASE2	Thin coax MAU as specified in Clause 10
10BROAD36	Broadband DTE MAU as specified in Clause 11
10BASE-T	UTP MAU as specified in Clause 14, duplex mode unknown
10BASE-THD	UTP MAU as specified in Clause 14, half duplex mode
10BASE-TFD	UTP MAU as specified in Clause 14, full duplex mode

10PASS-TS	Voice grade UTP PHY as specified in Clause 61 and 62
10BASE-FP	Passive fiber MAU as specified in Clause 16
10BASE-FB	Synchronous fiber MAU as specified in Clause 17
10BASE-FL	Asynchronous fiber MAU as specified in Clause 18, duplex mode unknown
10BASE-FLHD	Asynchronous fiber MAU as specified in Clause 18, half duplex mode
10BASE-FLFD	Asynchronous fiber MAU as specified in Clause 18, full duplex mode
100BASE-T4	Four-pair Category 3 UTP as specified in Clause 23
100BASE-TX	Two-pair Category 5 UTP as specified in Clause 25, duplex mode unknown
100BASE-TXHD	Two-pair Category 5 UTP as specified in Clause 25, half duplex mode
100BASE-TXFD	Two-pair Category 5 UTP as specified in Clause 25, full duplex mode
100BASE-BXT	Simplex fiber OLT PHY as specified in Clause 60
100BASE-BXU	Simplex fiber ONU PHY as specified in Clause 60
100BASE-FX	X fiber over PMD as specified in Clause 26, duplex mode unknown
100BASE-FXHD	X fiber over PMD as specified in Clause 26, half duplex mode
100BASE-FXFD	X fiber over PMD as specified in Clause 26, full duplex mode
100BASE-LX	Duplex fiber PHY as specified in Clause 60
100BASE-T2	Two-pair Category 3 UTP as specified in Clause 32, duplex mode unknown
100BASE-T2HD	Two-pair Category 3 UTP as specified in Clause 32, half duplex mode
100BASE-T2FD	Two-pair Category 3 UTP as specified in Clause 32, full duplex mode
1000BASE-X	X PCS/PMA as specified in Clause 36 over undefined PMD, duplex mode unknown
1000BASE-XHD	X PCS/PMA as specified in Clause 36 over undefined PMD, half duplex mode
1000BASE-XFD	X PCS/PMA as specified in Clause 36 over undefined PMD, full duplex mode
1000BASE-BX-OLT	Simplex fiber OLT PHY as specified in Clause 59
1000BASE-BX-ONU	Simplex fiber ONU PHY as specified in Clause 59
1000BASE-EX	Duplex fiber PHY as specified in Clause 59
1000BASE-LX	X fiber over long-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-LXHD	X fiber over long-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-LXFD	X fiber over long-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-PXAT	Simplex fiber OMP OLT Type A PHY as specified in Clause 58
1000BASE-PXAU	Simplex fiber OMP ONU Type A PHY as specified in Clause 58
1000BASE-PXBT	Simplex fiber OMP OLT Type B PHY as specified in Clause 58
1000BASE-PXBU	Simplex fiber OMP ONU Type B PHY as specified in Clause 58
1000BASE-SX	X fiber over short-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-SXHD	X fiber over short-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-SXFD	X fiber over short-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-CX	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, duplex mode unknown
1000BASE-CXHD	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, half duplex mode
1000BASE-CXFD	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, full duplex mode
1000BASE-T	Four-pair Category 5 UTP PHY to be specified in Clause 40, duplex mode unknown
1000BASE-THD	Four-pair Category 5 UTP PHY to be specified in Clause 40, half duplex mode
1000BASE-TFD	Four-pair Category 5 UTP PHY to be specified in Clause 40, full duplex mode
10GBASE-X	X PCS/PMA as specified in Clause 48 over undefined PMD
10GBASE-LX4	X fibre over 4 lane 1310nm optics as specified in Clause 53

10GBASE-R	R PCS/PMA as specified in Clause 49 over undefined PMD
10GBASE-ER	R fibre over 1550nm optics as specified in Clause 52
10GBASE-LR	R fibre over 1310nm optics as specified in Clause 52
10GBASE-SR	R fibre over 850nm optics as specified in Clause 52
10GBASE-W	W PCS/PMA as specified in Clauses 49 and 50 over undefined PMD
10GBASE-EW	W fibre over 1550nm optics as specified in Clause 52
10GBASE-LW	W fibre over 1310nm optics as specified in Clause 52
10GBASE-SW	W fibre over 850nm optics as specified in Clause 52
802.9a	Integrated services MAU as specified in IEEE Std 802.9 ISLAN-16T

BEHAVIOUR DEFINED AS:

Returns a value that identifies the internal MAU type. If an AUI is to be identified to access an external MAU, the type "AUI" is returned. A SET operation to one of the possible enumerations indicated by aMAUTypeList will force the MAU into the new operating mode. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the mode force bits specified in 22.2.4.1. If a Clause 45 MDIO Interface is present, then this will map to the PCS type selection bit(s) in the 10G WIS Control 2 register specified in 45.2.2.6.6 and in the 10G PCS Control 2 register specified in 45.2.3.6.1 and to the PMA/PMD type selection bits in the 10G PMA/PMD Control 2 register specified in 45.2.1.6.1. If Clause 28 or Clause 37 Auto-Negotiation is operational, then this will change the advertised ability to the single enumeration specified in the SET operation, and cause an immediate link renegotiation. A change in the MAU type will also be reflected in aPHYType.

The enumerations 1000BASE-X, 1000BASE-XHD, 1000BASE-XFD, 10GBASE-X, 10GBASE-R and 10GBASE-W shall only be returned if the underlying PMD type is unknown.;

Editors' Notes: *To be removed prior to final publication.*
1. Do we need a 'mode unknown' enumeration for the OLT/ONU PHYs

30.5.1.1.4 aMediaAvailable

Change this subclause as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

other	undefined
unknown	initializing, true state not yet known
available	link or light normal, loopback normal
not available	link loss or low light, no loopback
remote fault	remote fault with no detail
invalid signal	invalid signal, applies only to 10BASE-FB
remote jabber	remote fault, reason known to be jabber
remote link loss	remote fault, reason known to be far-end link loss
remote test	remote fault, reason known to be test
offline	offline, applies only to Clause 37 Auto-Negotiation
auto neg error	Auto-Negotiation Error, applies only to Clause 37 Auto-Negotiation
PMD link fault	PMD/PMA receive link fault
WIS frame loss	WIS loss of frame, applies only to 10GBASE-W
WIS signal loss	WIS loss of signal, applies only to 10GBASE-W
PCS link fault	PCS receive link fault
excessive BER	PCS Bit Error Rate monitor reporting excessive error rate
DXS link fault	DTE XGXS receive link fault, applies only to XAUI
PXS link fault	PHY XGXS transmit link fault, applies only to XAUI

BEHAVIOUR DEFINED AS:

If the MAU is a 10M b/s link or fiber type (FOIRL, 10BASE-T, 10BASE-F), then this is equivalent to the link test fail state/low light function. For an AUI, 10BASE2, 10BASE5, or 10BROAD36 MAU, this indicates whether or not loopback is detected on the DI circuit. The value of this attribute persists between packets for MAU types AUI, 10BASE5, 10BASE2, 10BROAD36, and 10BASE-FP.

At power-up or following a reset, the value of this attribute will be “unknown” for AUI, 10BASE5, 10BASE2, 10BROAD36, and 10BASE-FP MAUs. For these MAUs loopback will be tested on each transmission during which no collision is detected. If DI is receiving *input* when DO returns to IDL after a transmission and there has been no collision during the transmission, then loopback will be detected. The value of this attribute will only change during noncollided transmissions for AUI, 10BASE2, 10BASE5, 10BROAD36, and 10BASE-FP MAUs.

For 100BASE-T2, 100BASE-T4, 100BASE-TX, and 100BASE-FX the enumerations match the states within the respective link integrity state diagrams, Figures 32–17, 23–12 and 24–15. Any MAU that implements management of Clause 28 Auto-Negotiation will map remote fault indication to MediaAvailable “remote fault.” Any MAU that implements management of Clause 37 Auto-Negotiation will map the received RF1 and RF2 bits as specified in Table 37–2, as follows. Offline maps to the enumeration “offline,” Link_Failure maps to the enumeration “remote fault” and Auto-Negotiation Error maps to the enumeration “auto neg error.”

The enumeration “remote fault” applies to 10BASE-FB remote fault indication, the 100BASE-X far-end fault indication and nonspecified remote faults from a system running Clause 28 Auto-Negotiation. The enumerations “remote jabber~~,~~”, “remote link loss~~,~~”, or “remote test” should be used instead of “remote fault” where the reason for remote fault is identified in the remote signaling protocol.

Where a Clause 22 MII or Clause 35 GMII is present, a logic one in the remote fault bit (22.2.4.2.11) maps to the enumeration “remote fault~~,~~”, a logic zero in the link status bit (22.2.4.2.13) maps to the enumeration “not available~~.~~”. The enumeration “not available” takes precedence over “remote fault~~.~~”.

For 2BASE-TL and 10PASS-TS PHYs the enumeration 'available' maps to the condition where at least one PMI in the PHYs aggregation group (see *CROSS REF* 61.2.2) is operational, the enumeration 'not available' maps to the condition where no PMI is operational. For 100BASE-LX, 100BASE-BX, 1000BASE-LX, 1000BASE-BX and 1000BASE-PX PHYs the enumerations map to the respective link integrity state diagrams.

For 10 Gb/s the enumerations map to value of the link_fault variable within the Link Fault Signaling state diagram (Figure 46–9) as follows: the value OK maps to the enumeration “available”, the value Local Fault maps to the enumeration “not available” and the value Remote Fault maps to the enumeration “remote fault”. The enumeration “PMD link fault”, “WIS frame loss”, “WIS signal loss”, “PCS link fault”, “excessive BER” or “DXS link fault” should be used instead of the enumeration “not available” where the reason for the Local Fault state can be identified through the use of the Clause 45 MDIO Interface. Where multiple reasons for the Local Fault state can be identified only the highest precedence error should be reported. This precedence in descending order is as follows: “PXS link fault”, “PMD link fault”, “WIS frame loss”, “WIS signal loss”, “PCS link fault”, “excessive BER”, “DXS link fault”.

Where a Clause 45 MDIO interface is present a logic zero in the PMA/PMD Receive link status bit (45.2.1.2.2) maps to the enumeration “PMD link fault”, a logic one in the LOF status bit (45.2.2.10.4) maps to the enumeration “WIS frame loss”, a logic one in the LOS status bit (45.2.2.10.5) maps to the enumeration “WIS signal loss”, a logic zero in the PCS Receive link status bit (45.2.3.2.2) maps to the enumeration “PCS link fault”, a logic one in the 10GBASE-R PCS Latched high BER status bit (45.2.3.12.2) maps to the enmeration “excessive BER”, a logic zero in the DTE XS receive link status bit (45.2.5.2.2) maps to the enmeration “DXS link fault” and a logic zero in the PHY XS transmit link status bit (45.2.4.2.2) maps to the enmeration

"PXS link fault".

> ***Editors' Notes:*** *To be removed prior to final publication.*
> 1. This attribute will probably needs it behaviour updated due to at least one of the new PHYs

Insert this following new subclauses after 30.5.1.1.11 as follows:

30.5.1.1.12 aPCSCodingViolation

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 25 000 000 counts per second for 100 Mb/s implementations.

BEHAVIOUR DEFINED AS:

"For 100 Mb/ s operation it is a count of the number of times an invalid code-group is received, other than the /H/ code-group. For 1000 Mb/ s operation it is a count of the number of times an invalid code-group is received, other than the /V/ code-group.;

30.5.1.1.13 aPhySide

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value that has one of the following entries:

subscriber	subscribe mode of operation
office	office mode of operation

BEHAVIOUR DEFINED AS:

A read-write value that indicates the mode of operation of the PHY (see *CROSS REF* 61.1). A GET operation returns the current mode of operation. A SET operation changes the mode of operation to the indicated value.;

30.5.1.1.14 aPHYCurrentStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value that has one of the following entries:

noDefect
lossOfFraming
lossOfSignal
lossOfPower
lossOfSignalQuality
lossOfLink
dataInitFailure
configInitFailure
noPeerVtuPresent

BEHAVIOUR DEFINED AS:

This read-only value indicates the current operational state of the 10BASE-T PHY (see *CROSS REF* 62.5.6.3.3).;

30.5.1.1.15 aPMACorrectedBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of ???? counts per second for ??? Mb/s implementations.

> ***Editors' Notes:*** *To be removed prior to final publication.*
> Need to obtain the maximum increment rate for this counter.

BEHAVIOUR DEFINED AS:

A count of corrected FEC blocks. Increment the counter by one for each received block that is corrected by the FEC function in the 10PASS-TS PHY.;

30.5.1.1.16 aPMAUncorrectableBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of ???? counts per second for ??? Mb/s implementations.

> ***Editors' Notes:*** *To be removed prior to final publication.*
> Need to obtain the maximum increment rate for this counter.

BEHAVIOUR DEFINED AS:

A count of uncorrectable FEC blocks. Increment the counter by one for each FEC block received by the 10PASS-TS PHY that is determined to be uncorrectable.;

30.5.1.1.17 aPMDBand1SNR

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that indicates the SNR in Band 1 with respect to the received signal in dB/0.25 for the 10PASS-TS PHY (see *CROSS REF* 62.5.3, 62.4.4.2.2).;

30.5.1.1.18 aPMDBand2SNR

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that indicates the SNR in Band 2 with respect to the received signal in dB/0.25 for the 10PASS-TS PHY (see *CROSS REF* 62.5.3, 62.4.4.2.2).;

30.5.1.1.19 aPMDAttenuationLevelBand1

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that indicates the attenuation in Band 1 in dB/0.25 for the 10PASS-TS PHY (see

CROSS REF 62.5.3, 62.4.4.2.2).;

30.5.1.1.20 aPMDAttenuationLevelBand2

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only value that indicates the attenuation in Band 2 in dB/0.25 for the 10PASS-TS PHY (see *CROSS REF* 62.5.3, 62.4.4.2.2).;

30.5.1.1.21 aPMDInterleaverDepth

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-write value that indicates the interleaving depth of the 10PASS-TS PHY convolutional interleaver in bytes (see *CROSS REF* 62.3.2.2.9, 62.2.4.4). The interleaving depth has a range of 0 to 64 bytes. A GET operation returns the current interleaving depth. A SET operation changes the interleaving depth to the indicated value.;

30.5.1.1.22 aPMDInterleaverBlockSize

ATTRIBUTE

APPROPRIATE SYNTAX:
An INTEGER that meets the requirements of the description below:

25	interleaver block size of 25 bytes
50	interleaver block size of 50 bytes
100	interleaver block size of 100 bytes

BEHAVIOUR DEFINED AS:
A read-write value that indicates the interleaver block size of the 10PASS-TS PHY convolutional interleaver in bytes (see *CROSS REF* 62.3.2.2.9, 62.2.4.4). A GET operation returns the current interleaver block size. A SET operation changes the interleaver block size to the indicated value.;

30.5.1.1.23 aBandNotchProfile

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED value that has one of the following entries:

Editors' Notes: *To be removed prior to final publication.*

Enumerations are still TBD based on copper editor's final version of 62A.3.5

BEHAVIOUR DEFINED AS:
A read-write value that indicates the 10PASS-TS PHY egress control band notch profile (see *CROSS REF* 62A.3.5). A GET operation returns the current egress control band notch profile. A SET operation changes the egress control band notch profile to the indicated configuration.;

30.5.1.1.24 aPayloadRateProfileUpstream

ATTRIBUTE

APPROPRIATE SYNTAX:

An INTEGER that meets the requirements of the description below:

500	12 500Kbit/s data rate
350	8 750Kbit/s data rate
250	6 250Kbit/s data rate
150	3 750Kbit/s data rate
125	3 125Kbit/s data rate
100	2 500Kbit/s data rate
75	1 875Kbit/s data rate
50	1 250Kbit/s data rate
25	625Kbit/s data rate

BEHAVIOUR DEFINED AS:

A read-write value that indicates the upstream data rate of the 10PASS-TS PHY in kbit/s/25 (see *CROSS REF* 62A3.4). A GET operation returns the current upstream data rate. A SET operation changes the upstream data rate to the indicated value.;

30.5.1.1.25 aPayloadRateProfileDownstream

ATTRIBUTE

APPROPRIATE SYNTAX:

The same as used for aPayloadRateProfileUpstream

BEHAVIOUR DEFINED AS:

A read-write value that indicates the downstream data rate of the 10PASS-TS PHY in kbit/s/25 (see *CROSS REF* 62A3.4). A GET operation returns the current downstream data rate. A SET operation changes the downstream data rate to the indicated value.;

30.5.1.1.26 aBandplanPSDMaskProfile

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value that has one of the following entries:

Editors' Notes: *To be removed prior to final publication.*

Enumerations are still TBD based on copper editor's final version of 62A.3.3

BEHAVIOUR DEFINED AS:

A read-write value that indicates the 10PASS-TS PHY Bandplan PSD profile (see *CROSS REF* 62A.3.3). A GET operation returns the current Bandplan PSD profile. A SET operation changes the Bandplan PSD profile to the indicated configuration.;

30.5.1.1.27 aProfileSelect

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value that has one of the following entries:

1	operating profile 1
2	operating profile 2

3	operating profile 3
4	operating profile 4
5	operating profile 5
6	operating profile 6
7	operating profile 7
8	operating profile 8
9	operating profile 9
10	operating profile 10

BEHAVIOUR DEFINED AS:

A read-write value that indicates the 2BASE-TL PHY operating profile (see *CROSS REF* 63A.3). A GET operation returns the current operating profile. A SET operation changes the operating profile to the indicated profile.;

Insert the following after subclause 30.3.4.3

30.3.5 MPCP managed object class

This subclause formally defines the behaviours for the oMPCP managed object class attributes and actions.

30.3.5.1 MPCP Attributes

30.3.5.1.1 aMPCPAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:

A read-only value that identifies the operational state of the Multi-Point MAC Control sublayer. An interface which can provide the Multi-Point MAC Control sublayer functions specified in CROSS REF Clause 64 will be enabled to do so when this attribute has the enumeration “enable”. When this attribute has the enumeration “disable” the interface will act as it would if it had no Multi-Point MAC Control sublayer. The operational state of the Multi-Point MAC Control Sublayer can be changed using the acMPCPAdminControl action.;

30.3.5.1.2 aMPCPMode

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:
OLT
ONU

BEHAVIOUR DEFINED AS:

A read-only value that identifies the operational mode of the Multi-Point MAC Control sublayer. An interface which can provide the Multi-Point MAC Control sublayer functions specified in CROSS REF Clause 64 will be operate as an OLT when this attribute has the enumeration “OLT”. When this attribute has the enumeration “ONU” the interface will act as an ONU.;

30.3.5.1.3 aMPCPMACCtrlFramesTransmitted

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of MPCP frames passed to the MAC sublayer for transmission. This counter is incremented when a MA_CONTROL.request primitive is generated within the MAC Control sublayer with an opcode indicating a MPCP frame.;

30.3.5.1.4 aMPCPMACCtrlFramesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of MPCP frames passed by the MAC sublayer to the MAC Control sublayer. This counter is incremented when a ReceiveFrame function call returns a valid frame with: (1) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, and (2) an opcode indicating a MPCP frame.;

30.3.5.1.5 aMPCPLinkID

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that identifies the Logical Link identity (LLID) associated with the MAC port as specified in CROSS REF subclause 65.1.3.1.2.;

30.3.5.1.6 aMPCPRemoteMACAddress

ATTRIBUTE

APPROPRIATE SYNTAX:

MACAddress

BEHAVIOUR DEFINED AS:

A read-only value that identifies the source_address parameter of the last MPCPDUs passed to the MAC Control. This value is updated on reception of a valid frame with (1) a destinationField equal to the reserved multicast address for MAC Control specified in CROSS REF 31A, (2) lengthOrType field value equal to the reserved Type for MAC Control as specified in CROSS REF 31A, (3) an MPCP subtype value equal to the subtype reserved for MPCP as specified in CROSS REF 31A.;

30.3.5.1.7 aMPCPRegistrationState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:
unregistered
registering
registered

BEHAVIOUR DEFINED AS:

A read-only value that identifies the operational state of the Multi-Point MAC Control sublayer. When this attribute has the enumeration 'unregistered' the interface may be used for registering a link partner. When this attribute has the enumeration 'registering' the interface is in the process of registering a link-partner. When this attribute has the enumeration 'registered' the interface has an established link-partner.;

30.3.5.1.8 aMPCPTransmitElapsed

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that reports the interval from last MPCP frame transmission in ns/16. Where the interval exceeds (2^{32}-1) x 16ns the value 2^{32}-1 shall be returned.;

30.3.5.1.9 aMPCPReceiveElapsed

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that reports the interval from last MPCP frame reception in ns/16. Where the interval exceeds (2^{32}-1) x 16ns the value 2^{32}-1 shall be returned.;

30.3.5.1.10 aMPCPRoundTripTime

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that reports the MPCP round trip time in ns/16. Where the interval exceeds (2^{16}-1) x 16ns the value 2^{16}-1 shall be returned.;

30.3.5.1.11 aMPCPDiscoveryWindowsSent

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 10 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of discovery windows generated. Increment the counter by one for each discovery windows generated.;

30.3.5.1.12 aMPCPRegistrationAttempts

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 10 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of number of attempts to perform registration. Increment the counter by one for each attempt to perform registration.;

30.3.5.1.13 aMPCPDiscoveryTimeout

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of ??? counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a discovery timeout occurs. Increment the counter by one for each discovery processing state-machine reset resulting from timeout waiting for message arrival.;

30.3.5.1.14 aMPCPMaximumPendingGrants

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only value that indicates the maximum number of grants an ONU can store. The maximum number of grants an ONU can store has a range of 0 to 255.;

30.3.5.2 MPCP Actions

30.3.5.2.1 acMPCPAdminControl

ACTION

APPROPRIATE SYNTAX:
Same as aMPCPAdminState

BEHAVIOUR DEFINED AS:
This action provides a means to alter aMPCPAdminState.;

Insert the following new table after subclause 30.10.5.2.1

30.11 Management for Operations, Administration and Maintenance

30.11.1 OAM object class

This subclause formally defines the behaviours for the oOAM managed object class attributes.

30.11.1.1 OAM Attributes

30.11.1.1.1 aOAMID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aOAMID is assigned so as to uniquely identify an OAM entity among the subordinate managed objects of the containing object.;

30.11.1.1.2 aOAMAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:
A read-only value that identifies the operational state of the OAM sublayer. An interface which can provide the OAM sublayer functions specified in *CROSS REF* Clause 57 will be enabled to do so when this attribute has the enumeration 'enable'. When this attribute has the enumeration 'disable' the interface will act as it would if it had no OAM sublayer. The operational state of the OAM Sublayer can be changed using the acOAMAdminControl action.

30.11.1.1.3 aOAMMode

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:

passive	passive OAM mode
active	active OAM mode

BEHAVIOUR DEFINED AS:
A GET operation returns the current mode of the OAM sublayer entity (see *CROSS REF* 57.2.6), either passive or active.
A SET operation changes the mode of operation of the OAM entity to the indicated value. A SET operation shall have no effect on a device whose mode cannot be changed through management or that can only operate in a single mode.;

30.11.1.1.4 aOAMRemoteMACAddress

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
The value of the source_address parameter of the last OAMPDU passed by the OAM subordinate sublayer to the OAM sublayer. This value is updated on reception of a valid frame with (1) a destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3.;

30.11.1.1.5 aOAMRemoteConfiguration

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (3)]

BEHAVIOUR DEFINED AS:
A string of three bits corresponding to the OAM_Configuration field (see *CROSS REF* Table 57-7) in the most recently received Information OAMPDU. The first bit corresponds to the OAM_Mode bit in the OAM_Configuration field. The second bit corresponds to the Unidirectional_Support bit in the OAM_Configuration field. The third bit corresponds to the Loopback_Support bit in the OAM_Configuration field.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the OAM Information code.;

30.11.1.1.6 aOAMRemotePDUConfiguration

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
An eleven bit value corresponding to the Maximum_PDU_Size value within the OAMPDU_Configuration field (see *CROSS REF* Table 57-8) in the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the OAM Information code.;

30.11.1.1.7 aOAMLocalFlagsField

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (3)]

BEHAVIOUR DEFINED AS:
A string of three bits corresponding to the Flags field (see *CROSS REF* Table 57-3) in the most

recently transmitted OAMPDU. The first bit corresponds to the Link Fault bit in the Flags field. The second bit corresponds to the Dying Gasp bit in the Flags field. The third bit corresponds to the Critical Event bit in the Flags field.;

30.11.1.1.8 aOAMRemoteFlagsField

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (3)]

BEHAVIOUR DEFINED AS:
A string of three bits corresponding to the Flags field (see *CROSS REF* Table 57-3) in the most recently received OAMPDU. The first bit corresponds to the Link Fault bit in the Flags field. The second bit corresponds to the Dying Gasp bit in the Flags field. The third bit corresponds to the Critical Event bit in the Flags field.;

30.11.1.1.9 aOAMRemoteState

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (4)]

BEHAVIOUR DEFINED AS:
A string of four bits corresponding to the State field (see *CROSS REF* Table 57-6) of the most recently received Information OAMPDU. The first bit corresponds to the Stable bit in the State field. The second and third bits corresponds to the Parser Action bits in the State field. The fourth bit corresponds to the Multiplexer Action bit in the State field.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) a OAMPDU code equal to the Information code as specified in *CROSS REF* Table 57-5.;

30.11.1.1.10 aOAMRemoteVendorOUI

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of the OUI variable in the Vendor Identifier field (see *CROSS REF* Table 57-9) of the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) a OAMPDU code equal to the Information code as specified in *CROSS REF* Table 57-5.;

30.11.1.1.11 aOAMRemoteVendorIdDeviceNumber

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of the Device_Identifier variable in the Vendor Identifier field (see *CROSS REF* Table 57-9) of the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) a OAMPDU code equal to the Information code as specified in *CROSS REF* Table 57-5.;

30.11.1.1.12 aOAMRemoteVendorIdVersion

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of the Version_Identifier variable in the Vendor Identifier field (see *CROSS REF* Table 57-9) of the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) a OAMPDU code equal to the Information code as specified in *CROSS REF* Table 57-5.;

30.11.1.1.13 aOAMPDUTx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:
A count of OAMPDUs passed to the OAM subordinate sublayer for transmission. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer.;

30.11.1.1.14 aOAMPDURx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:
A count of OAMPDUs passed by the OAM subordinate sublayer to the OAM sublayer. This

counter is incremented on reception of a valid frame with (1) a destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3.;

30.11.1.1.15 aOAMUnsupportedCodesRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain an OAM code from *CROSS REF* Table 57-4 that are not supported by the device. This counter is incremented on reception of a valid frame with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) an OAM code for a function that is not supported by the device.;

30.11.1.1.16 aOAMInformationTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the OAM Information code specified in Table *CROSS REF* 57-4. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer with an OAM code indicating an OAM Information operation.;

30.11.1.1.17 aOAMInformationRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the OAM Information code specified in *CROSS REF* Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the OAM Information code.;

30.11.1.1.18 aOAMEventNotificationTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Event Notification code specified in *CROSS REF* Table 57-4. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer with an OAM code indicating a Event Notification operation.;

30.11.1.1.19 aOAMUniqueEventNotificationRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of the OAMPDUs received that contain the Event Notification code specified in CROSS REF Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in CROSS REF Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in CROSS REF Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in CROSS REF Table 43B-3, (4) the OAM code equals the Event Notification code, (5) the Sequence Number field is not equal to the Sequence Number field of the last received Event Notification OAMPDU.;

30.11.1.1.20 aOAMDuplicateEventNotificationRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of the OAMPDUs received that contain the Event Notification code specified in CROSS REF Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in CROSS REF Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in CROSS REF Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in CROSS REF Table 43B-3, (4) the OAM code equals the Event Notification code, (5) the Sequence Number field is equal to the Sequence Number field of the last received Event Notification OAMPDU.;

30.11.1.1.21 aOAMLoopbackControlTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Loopback Control code specified in *CROSS REF* Table 57-4. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer with an OAM code indicating a Loopback Control operation.;

30.11.1.1.22 aOAMLoopbackControlRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the Loopback Control code specified in *CROSS REF* Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the Loopback Control code.;

30.11.1.1.23 aOAMVariableRequestTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Variable Request code specified in Table *CROSS REF* 57-4. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer with an OAM code indicating a Variable Request operation.;

30.11.1.1.24 aOAMVariableRequestRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the Variable Request code specified in *CROSS REF* Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the Variable Request code.;

30.11.1.1.25 aOAMVariableResponseTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Variable Response code specified in *CROSS REF* Table 57-4. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer with an OAM code indicating a Variable Response operation.;

30.11.1.1.26 aOAMVariableResponseRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:
A count of OAMPDUs received that contain the Variable Response code specified in *CROSS REF* Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the Variable Response code.;

30.11.1.1.27 aOAMOrganizationSpecificTx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:
A count of Organization Specific OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Organization Specific code specified in *CROSS REF* Table 57-4. This counter is incremented when a Mux:MA_DATA.request primitive is generated within the OAM sublayer with an OAM code indicating a Organization Specific operation.;

30.11.1.1.28 aOAMOrganizationSpecificRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in *CROSS REF* 43B.2.

BEHAVIOUR DEFINED AS:
A count of OAMPDUs received that contain the Organization Specific code specified in *CROSS REF* Table 57-4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in *CROSS REF* Table 43B-1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in *CROSS REF* Table 43B-2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in *CROSS REF* Table 43B-3, (4) the OAM code equals the Organization Specific code.;

30.11.1.1.29 aOAMLocalErrSymPeriodWindow

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
An eight-octet value indicating the duration of the Errored Symbol Period Event (see *CROSS REF*

57.5.3.1) window, in terms of symbols.

30.11.1.1.30 aOAMLocalErrSymPeriodThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A four-octet value indicating the number of errored symbols in the period that must be exceeded in order for the Errored Symbol Period Event (see *CROSS REF* 57.5.3.1) to be generated.

30.11.1.1.31 aOAMLocalErrSymPeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of two instances of the type INTEGER
The first INTEGER represents the number of symbols in the period
The second INTEGER represents the number of errored symbols in the period

BEHAVIOUR DEFINED AS:
A sequence of two integers corresponding to the value field in the most recently transmitted Errored Symbol Period Event TLV in a Event Notification OAMPDU (see *CROSS REF* 57.5.3.1).;

30.11.1.1.32 aOAMLocalErrFrameSecsWindow

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A four-octet value indicating the duration of the Errored Frame Seconds Event (see *CROSS REF* 57.5.3.2) window, in terms of number of 100ms intervals.

30.11.1.1.33 aOAMLocalErrFrameSecsThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A four-octet field indicating the number of errored frames in the period that must be exceeded in order for the Errored Frame Seconds Event (see *CROSS REF* 57.5.3.2) to be generated.

30.11.1.1.34 aOAMLocalErrFrameSecsEvent

ATTRIBUTE
APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER
The first INTEGER represents the number of seconds in the period
The second INTEGER represents the number of errored frames in the period

BEHAVIOUR DEFINED AS:
A sequence of two integers corresponding to the value field in the most recently transmitted Errored Frame Seconds Event TLV in a Event Notification OAMPDU (see *CROSS REF*

57.5.3.2).;

30.11.1.1.35 aOAMLocalErrFramePeriodWindow

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A four-octet value indicating the duration of the Errored Frame Period Event (see *CROSS REF* 57.5.3.3) window, in terms of the number of minFrameSize frames that can be transmitted on the underlying physical layer.

30.11.1.1.36 aOAMLocalErrFramePeriodThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A four-octet field indicating the number of errored frames in the period that must be exceeded in order for the Errored Frame Period Event (see *CROSS REF* 57.5.3.3) to be generated.

30.11.1.1.37 aOAMLocalErrFramePeriodEvent

ATTRIBUTE
APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER
The first INTEGER represents the number of frames in the period
The second INTEGER represents the number of errored frames in the period

BEHAVIOUR DEFINED AS:
A sequence of two integers corresponding to the value field in the most recently transmitted Errored Frame Period Event TLV in an Event Notification OAMPDU (see *CROSS REF* 57.5.3.3).;

30.11.1.1.38 aOAMLocalErrFrameSecsSummaryWindow

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A two-octet value indicating the duration of the Errored Frame Seconds Summary Event (see *CROSS REF* 57.5.3.4) window, in terms of number of 100ms intervals.

30.11.1.1.39 aOAMLocalErrFrameSecsSummaryThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A two-octet field indicating the number of errored frame seconds in the period that must be exceeded in order for the Errored Frame Seconds Summary Event (see *CROSS REF* 57.5.3.4) to be generated.

30.11.1.1.40 aOAMLocalErrFrameSecsSummaryEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER

The first INTEGER represents the number of seconds in the period

The second INTEGER represents the number of errored frame seconds in the period

BEHAVIOUR DEFINED AS:

A sequence of two integers corresponding to the value field in the most recently transmitted Errored Frame Seconds Summary Event TLV in an Event Notification OAMPDU (see *CROSS REF* 57.5.3.4).;

30.11.1.1.41 aOAMRemoteErrSymPeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of three instances of the type INTEGER

The first INTEGER represents the time stamp of the event

The second INTEGER represents the number of symbols in the period

The third INTEGER represents the number of errored symbols in the period.

BEHAVIOUR DEFINED AS:

A sequence of three integers corresponding to the value field in the most recently received Errored Symbol Period Event TLV in an Event Notification OAMPDU (see *CROSS REF* 57.5.3.1).;

30.11.1.1.42 aOAMRemoteErrFrameSecsEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of three instances of the type INTEGER

The first INTEGER represents the time stamp of the event.

The second INTEGER represents the number of 100ms intervals in the period.

The third INTEGER represents the number of errored frames in the period

BEHAVIOUR DEFINED AS:

A sequence of three integers corresponding to the value field in the most recently received Errored Frame Seconds Event TLV in an Event Notification OAMPDU (see *CROSS REF* 57.5.3.2).;

30.11.1.1.43 aOAMRemoteErrFramePeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of three instances of the type INTEGER

The first INTEGER represents the time stamp of the event

The second INTEGER represents the number of minFrameSize frames that could be transmitted in the period

The third INTEGER represents the number of errored frames in the period

BEHAVIOUR DEFINED AS:

A sequence of three integers corresponding to the value field in the most recently received Errored Frame Period Event TLV in an Event Notification OAMPDU (see *CROSS REF* 57.5.3.3).;

30.11.1.1.44 aOAMRemoteErrFrameSecsSummaryEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of three instances of the type INTEGER
The first INTEGER represents the time stamp of the event.
The second INTEGER represents the number of 100ms intervals in the period.
The third INTEGER represents the number of errored frame seconds in the period

BEHAVIOUR DEFINED AS:

A sequence of three integers corresponding to the value field in the most recently received Errored Frame Seconds Summary Event TLV in an Event Notification OAMPDU (see *CROSS REF* 57.5.3.4).;

30.11.1.1.45 aFramesLostDueToOAMError

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that would otherwise be transmitted by the OAM sublayer, but could not be due to an internal OAM sublayer transmit error. If this counter is incremented, then none of the other counters in this section are incremented. The exact meaning and mechanism for incrementing this counter is implementation dependent.;

30.11.1.2 OAM Actions

30.11.1.2.1 acOAMAdminControl

ACTION

APPROPRIATE SYNTAX:

Same as aPortAdminState

BEHAVIOUR DEFINED AS:

This action provides a means to alter aOAMAdminState.;

30.12 Management for OMP

> ***Editors' Notes:*** *To be removed prior to final publication.*
> Need to agree a better object names instead of 'oEPONMuxing' and 'oEPONEmulation'.

30.12.1 OMPMuxing managed object class

This subclause formally defines the behaviours for the oOMPMuxing managed object class attributes.

> ***Editors' Notes:*** *To be removed prior to final publication.*
> 1. Need to add additional oEPONMuxing attributes, actions and notifications as required.

30.12.2 OMPEmulation managed object class

This subclause formally defines the behaviours for the oOMPEmulation managed object class attributes.

30.12.2.1 OMPEmulation Attributes

30.12.2.1.1 aOMPEmulationID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aOAMID is assigned so as to uniquely identify a OMPEmulation entity among the subordinate managed objects of the containing object.;

30.12.2.1.2 aSPDErrors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames received that do not contain a valid SPD field as defined in *CROSS REF* 57.3.2.1.;

30.12.2.1.3 aCRC8Errors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames received that contain a valid SPD field, as defined in *CROSS REF* 57.3.2.1, but do not pass the CRC-8 check as defined in *CROSS REF* 57.3.2.3.;

30.12.2.1.4 aBadLLID

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames received that contain a valid SPD field, as defined in CROSS REF 57.3.2.1, and pass the CRC-8 check, as defined in CROSS REF 57.3.2.3, but are discarded due to the LLID check as defined in CROSS REF 57.3.2.2.;

Editors' Notes: *To be removed prior to final publication.*
1. Need to add additional oEPONEmulation attributes, actions and notifications as required.

Example attribute - LLID errors: packets discarded due to errors in LLID

Changes to ANSI/IEEE Std 802.3, 2002, Clause 36

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or <u>underscore</u> (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions:

None.

Abbreviations:

None.

Issues:

a) Need to add oam_enable to MDIO register bit 6.5(?) in Clause 22. - Closed - Added bit 0.1 in Clause 22.
b) Need to explain to the user when oam_enable is set, mr_an_enable should be clear. - Closed - Added in Clause 22.
c) Tables 36-1,2 & 3 need to be re-anchored (somehow). - Closed - Leave up to IEEE editor.

Revision History:

Draft 0.91	August 2002	Initial draft for IEEE P802.3ah Editors' review.
Draft 1.0	August 2002	Reduce content of file to changes only.
Draft 1.1	October 2002	Added Coding Violation Counter per comment #1003.
		Added "Burst Mode Specifications" subclause per comment #383.
		Closed all issues (above).
Draft 1.2	November 2002	Cleaned up tabs in this section
		Remove "bits" in 36.2.4.19
		Added text excluding /V/ from incrementing coding_violation_counter
		Change "OAM capability" to "unidirectional OAM Capability" in 36.2.5.1.3
		Change "mr_oam_enable" to "mr_unidirectional_oam_enable" in 36.2.5.1.3
		Remove "bit" in 36.2.5.1.3
		Correct spelling "equalt" to "equal" in 36.3.9
Draft 1.3		Correct references in comments above
		Change "mr_oam_enable" to "mr_unidirectional_oam_enable" in all other places
		Add PICs entry for new "shall" statement in 36.3.9
		Clean up numbering sources for cleaner editorial changes
		Added cross references
Draft 1.414	April 2003	Get new reference to register bits for coding violation counter
		Add descriptive text in modified definition of xmit variable

36. Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 1000BASE-X

Insert new subclause:

36.2.4.19 PCS Management Counter

The following counter applies to PCS management. If an MDIO interface is provided (see *CROSS REF* Clause 22), it is accessed via that interface. If not, it is recommended that an equivalent access be provided. This counter is reset to zero upon read or upon reset of the PCS. When it reaches all ones, it stops counting. Its purpose is to help monitor the quality of the link.

coding_violation_counter:

> 16-bit counter. When the receiver is in normal mode, coding_violation_counter counts once for each invalid code-group received. The single code-group Error_Propagation ordered_set (/V/) is not considered an invalid code-group and as such is not counted when received. This counter is reflected in *CROSS REF* 45.2.1.

36.2.5.1.3 Variables

Insert new variable in proper alphabetical location:

mr_unidirectional_oam_enable

> Controls the enabling and disabling of unidirectional OAM capability. This bit reflects the value in MDIO register 0.1.
>
> Values: FALSE; Unidirectional OAM capability is not enabled
> TRUE; Unidirectional OAM capability is enabled

Modify the following variable:

xmit

> When mr_unidirectional_oam_enable=FALSE, xmit is d~~D~~efined in *CROSS REF* 37.3.1.1. When mr_unidirectional_oam_enable=TRUE, xmit always takes the value DATA.

36.2.5.2.1 Transmit

Modify the second paragraph as follows:

The Transmit ordered_set process continuously sources ordered_sets to the Transmit code-group process. When mr_unidirectional_oam_enable = TRUE, the Auto-Negotiation process xmit flag always takes the value DATA and the Auto-Negotiation process is never invoked. Otherwise, when initially invoked, and when the Auto-Negotiation process xmit flag indicates CONFIGURATION, the Auto-Negotiation process is invoked. When the Auto-Negotiation process xmit flag indicates IDLE, and between packets (as delimited by the GMII), /I/ is sourced. Upon the assertion of TX_EN by the GMII when the Auto-Negotiation process xmit flag indicates DATA, the SPD ordered_set is sourced. Following the SPD, /D/ code-groups are sourced until TX_EN is deasserted. Following the de-assertion of TX_EN, EPD ordered_sets are sourced. If TX_ER is asserted when TX_EN is deasserted and carrier extend error is not indicated by TXD, /R/ ordered_sets are sourced for as many GTX_CLK periods as TX_ER is asserted with a delay of two GTX_CLK periods to first source the /T/ and /R/ ordered sets. If carrier extend error is indicated by TXD during carrier extend, /V/ ordered_sets are sourced. If TX_EN and TX_ER are both de-asserted, the /R/ ordered_set may be sourced, after which the sourcing of /I/ is resumed. If, while TX_EN is asserted, the TX_ER signal is asserted, the /V/ ordered_set is sourced except when the SPD ordered set is selected for sourcing.

Changes to ANSI/IEEE Std. 802.3, 2002, Clause 45

Editors' Notes: *To be removed prior to final publication.*

References:

None

Definitions ***(to be added to 1.4):***

aggregation group - a collection of PMIs that may be aggregated according to a particular implementation of the PMI aggregation function. See 61.2.2

downstream - transmission from the -O port to the -R port.

upstream - transmission from the -R port to the -O port.

Abbreviations ***(to be added to 1.5):***

PAF - PMI Aggregation Function
PMI - Physical Medium Independent
US - Upstream
DS - Downstream
EFM Cu- Ethernet in the First Mile -- generically pertaining to 10PASS-TS and 2BASE-TL port types

Revision History:

Draft 1.0 August 2002 Preliminary draft for IEEE P802.3ah Task Force review
Draft 1.1 October 2002 Draft for IEEE P802.3ah Task Force review
Draft 1.3 January 2003 Draft for IEEE P802.3ah Task Force review, incorporating changes resolved in the January 2003 interim meeting in Vancouver, Canada
Draft 1.414 April 2003 Draft for IEEE P802.3ah Task Force review, incorporating changes resolved in the January 2003 interim meeting in Dallas, Texas

45. Management Data Input/Output (MDIO) Interface

Editor's Note: This document will be folded into Clause 45 text once 802.3ae is completed. Because the IEEE standards publications editor had not completed the work on Clause 45 at the time this document was written, the following text was not formatted as a series of change instructions to Clause 45 of 802.3ae. This will be performed in the next draft.

Editor's Note: Certain topics have yet to be discussed. These include: registers for link activation and status, PMA/PMD registers for Clause 63, etc. Comments on other topics that need registers are welcome!

Editor's Note: The actual addresses for many of the registers defined below are TBD. They are represented by the character 'x' in the tables.

Editor's Note: Clause 22 register functionality may be required for EFM PHYs. We need to investigate whether supporting a subset of Clause 22 registers is required for EFM-Cu, or if some of the C22 functions need to be brought over into C45. In particular, check out the advertisement and applicability of PAUSE.

45.1 Handling of -O and -R port sub-types

The EFM Cu PHYs, 10PASS-TS and 2BASE-TL, each have two port sub-types, 10PASS-TS-O, 10PASS-TS-R, 2BASE-TL-O and 2BASE-TL-R. Hereafter, referred to generically as "-O" and "-R".

The "-O" sub-type corresponds to the port located at the service provider side of a subscriber link (the central office). The "-R" sub-type corresponds to the port located at the customer side of a subscriber link (the remote side). See (**unwritten text in Clause 61**) for more information.

Two ports of the same sub-type do not link together. A functional link can only exist between an "-O" and "-R" pair. In general, the "-O" device acts as the master, the -"R" cannot set its own configuration. For most registers, the "-R" STA may only perform register reads.

Many registers have different behavior on "-O" vs. "-R" ports. Registers that correspond to *local* parameters are read/write on "-O" ports and are read-only on "-R" ports. Registers historically defined in Clauses 22 and 45 have always been *local*. This concept is extended to suit the asymmetric management model of subscriber networks:

To configure the "-R" ports, many local registers have duals, named "Remote" registers that are used by the "-O" STA to configure the "-R" port. These "Remote" registers are undefined for the "-R" STA. In these cases where definition or behavior differs from "-O" to "-R" ports, the bit definition table will indicate such by showing two marks in the "R/W" field.

For example, the Constellation register (45.4.1.9) bits have "O: R/W, R: RO" marked in their "R/W" field. This means that while the "-O" STA may set it's local constellation parameters, the "-R" STA may only view the parameters on it's local port. In this case, the dual is the Remote Constellation register (45.4.1.10). These bits are marked in their "R/W" field as "O: R/W, R: undefined". This means that the "-O" may set and view this register to configure the "-R". Since the "-R" STA may not configure the "-O" port, the register is undefined for "-R" ports.

"Remote" configuration registers that take effect immediately are marked in their "R/W" field with an additional "N." For example, see the Remote PMA Control register (45.3.1.4, Table 45–18), bit 15. When the "-O" STA sets this bit, the "-R" link partner will immediately begin transmitting FEC errors.

In some cases, this remote configuration occurs only upon link activation, as noted in the individual register descriptions. These registers are marked in their R/W field with the notation “I”.

In other cases, the “-R” link parameters may be changed during link operation. To ensure that the “-R” port does not switch modes until the “-O” STA is ready, writing these registers do not take immediate effect on the “-R” port. Instead, the register settings take effect when the corresponding “activate” command is issued in a separate “-O” register”. “-R” registers that do not take immediate effect are marked in their “R/W” field with the notation “D”.

For example, the constellation set for a carrier must be the same on both sides of the link. To change constellations, the “-O” STA would first write the new constellation values in the Remote Constellation register (45.4.1.10). When all of the values are written, the “-O” STA would then set the Activate constellation bits in the Remote Parameter Activate register (45.4.1.1). This tells the “-R” PMD to switch to the new values. The “-O” STA may now set it’s new constellation values to its Constellation register (45.4.1.9), which take immediate effect and establishing a link with the “-R” port at the new constellation.

45.2 PCS registers

Unless otherwise specified, the PCS registers are common for all EFM-Cu port types. The additional PCS registers are shown in Table 45–1

Table 45–1—PCS registers to add to Clause 45

Register address	Register name
3.44	PHY-MAC Rate Matching register
3.45, 46	PMD Available register
3.47,48	PMD Aggregate register
3.49	Aggregation Discover Control register
3.50,51,52	Aggregation Discovery code register
3.53	PAF RX error register
3.54	PAF small fragment register
3.55	PAF fragment too large register
3.56	PAF overflow register
3.57	PAF lost fragment register

45.2.1 Coding Violation Counter register. (Register TBD)

Table 45–2—Coding Violation Counter register bit definitions

Bit(s)	Name	Description	R/W
3.TDB.15:0	Coding Violation Counter	Error counter	RO, CR[a]

[a]indicates that the register clears itself when read

The assignment of bits in the Coding Violation Counter register is shown in Table 45–2. The Coding Violation Counter is a sixteen bit counter that contains the number of coding violations received during normal operation (see 24.2.2.1.7 or 36.2.4.19). These bits shall be reset to all zeroes when the Coding Violation Counter is read by the management function or upon execution of the PCS reset. These bits shall be held at all ones in the case of overflow

45.2.2 EFM Cu General registers

45.2.2.1 EFM Cu PHY Control register

The PHY capability register controls general functions of the PHY. This register is present at the PCS layer for each PHY. The bit definitions of the EFM Cu PHY Control register are shown in Table 45–3.

Table 45–3—EFM Cu Control register bit definitions

Bit(s)	Name	Description	R/W
3.x.15	Port sub-type select	0 = port shall operate as a R sub-type 1 = port shall operate as an O sub-type	R/W
3.x.13:0	reserved	Value always 0, writes ignored	R/W

45.2.2.1.1 Port sub-type select (3.x.15)

This register bit selects the port sub-type that the PHY shall operate as. **(see UNWRITTEN TEXT)** for more information on the EFM Cu port sub-types. The bit defaults to a supported mode. Writes to change to an unsupported mode are ignored.

45.2.3 EFM Cu PHY-MAC Rate Matching PCS function registers

45.2.3.1 PHY-MAC Rate Matching register

The assignment of bits in the PHY-MAC Rate Matching register is shown in Table 45–4.

45.2.3.1.1 MII receive during transmit (3.44.15)

This register bit is used to tell the PHY-MAC rate matching function if the MAC is capable of receiving frames from the PHY while the MAC is transmitting (i.e. sending frames to the PHY). The variable tx_rx_simultaneously for the PHY-MAC Rate-Matching function takes on the value of this but as defined in 61.2.1.3.2

Table 45–4—PHY-MAC Rate Matching register bit definitions

Bit(s)	Name	Description	R/W
3.44.15	MII receive during transmit	1 = MII can TX/RX simultaneously 0 = MII cannot TX/RX simultaneously. (default)	R/W[a]
3.44.14	TX_EN and CRS infer a collision	1 = MII uses TX_EN and CRS to infer a collision 0 = MII uses COL to indicate a collision (default)	R/W
3.44.13:0	Reserved	Value always 0, writes ignored	R/W

[a]RW = Read/Write

45.2.3.1.2 TX_EN and CRS infer a collision (3.44.14)

This bit is set for exposed MAC-PHY interfaces that do not have a separate collision signal but infer a collision when TX_EN and CRS are asserted simultaneously. The variable crs_and_tx_en_infer_col in the PHY-MAC Rate-Matching function takes on the value of this bit as in 61.2.1.3.2.

45.2.4 PMI Aggregation PCS function registers

Editor's Note: The following registers are used to control the PMI aggregation function as well as to facilitate the discovery of the "-R" port's PMI aggregation capabilities.

The following text refers to the concept of a "Remote Discovery Register." This register is not a Clause 45 object, but a variable of the PMI Aggregation PCS function on "-R" ports. The definition of this register should be written as part of 61.1.4.1. Perhaps there could be a better name for the "Remote Discovery Register."

The mechanisms that the registers below control are not yet defined as part of Clauses 61,62 or 63. In particular, the PHY-level messaging to facilitate the remote discovery process needs to be written for each port type's PMA.

45.2.4.1 PMI Available register

The PMI Available register is used to indicate which other PMIs in the aggregation group are available to be aggregated with the queried PMI. A PMI is marked as unavailable if: the PMI does not support PMI aggregation or if the PMI is currently marked to be aggregated with another PMD.

This register may optionally be writable for "-R" ports. For PMIs that may be accessed through more than one MII, the availability shall be limited such that no PMI may be mapped to more than one MII prior to enabling the links.

In this case, the reset state of the PMI_available_register shall reflect the capabilities of the device, the management entity must reset appropriate bits to meet the restriction described.

If the "-R" device is not capable of aggregating PMIs to multiple MIIs then the PMI Available Register may be read only.

The PMI Available register shall be implemented as a single instance across all PCS MMDs in a package. Reads and writes to any PCS MMD in the same package affect this single instance equally. For example, a package implementing four EFM Cu PHYs would have only one PMI Available register, addressed by a read or write to 3.45 on any of those PHYs.

The assignment of bits in the PMI Available registers is shown in Table 45–5.

Table 45–5—PMI Available register bit definitions

Bit(s)	Name	Description	R/W
3.45.15:0	PMI [p = 32:17] available	For each bit in the sequence: 1 = PMI[p] is available for aggregating 0 = PMI[p] is unavailable	O: RO[a] R: R/W[b]
3.46.15:0	PMI [p = 16:1] available	For each bit in the sequence: 1 = PMI[p] is available for aggregating 0 = PMI[p] is unavailable	O: RO R: R/W

[a]RO = Read Only
[b]RW = Read/Write

45.2.4.2 PMI Aggregate register

The PMI Aggregate register is used to turn on PMI aggregation between the addressed PMI and other PMIs in the aggregation group. Attempts to activate aggregation with an unavailable PMI (See 45.2.4.1) are ignored.

The PMI Aggregate register shall be implemented as a single instance across all PCS MMDs in a package. Reads and writes to any PCS MMD in the same package affect this single instance equally. For example, a package implementing four EFM Cu PHYs would have only one PMI Aggregate register, accessed by a read or write to 3.47 on any of those PHYs.

The assignment of bits for the PMI Aggregate register is shown in Table 45–6

Table 45–6—PMI Aggregate register bit definitions

Bit(s)	Name	Description	R/W
3.47.15:0	Aggregate with PMI [p = 32:17]	For each bit in the sequence: 1 = activate aggregation with PMI[p] 0 = deactivate aggregation with PMI[p]	R/W[a]
3.48.15:0	Aggregate with PMI [p = 16:1]	For each bit in the sequence: 1 = activate aggregation with PMI[p] 0 = deactivate aggregation with PMI[p]	R/W

[a]RW = Read/Write

45.2.4.3 Aggregation Discovery Control register

The Aggregation Discovery Control register allows the STA of an “-O” port to determine the aggregation capabilities of an “-R” link-partner.

The Aggregation Discover Control register shall be implemented as a unique register for each PCS MMDs in a package. For example, a package implementing four EFM Cu PHYs would have four independent instances of the Aggregation Discover Control register, accessed by a read or write to 3.49 to each PHY.

This register is defined only for "-O" ports. The register bit definitions are shown in Table 45–7

Table 45–7—Aggregation Discovery Control register bit definitions

Bit(s)	Name	Description	R/W
3.49.15:14	Discovery operation	01 = Ready (default) 00 = Set if clear 11 = Clear if same 10 = Get	R/W[a]
3.49.13	Discovery operation result	0 = discovery operation completed successfully (default) 1 = operation unsuccessful	RO[b], LH[c]
3.49.12:0	reserved	Value always 0, writes ignored	R/W

[a]RW = Read/Write
[b]RO = Read Only
[c]LH = Latches High

45.2.4.3.1 Discovery operation (3.x.15:14)

Editor's Note: The mechanism behind these bits needs to be fleshed out in Clauses 61,62, and 63

The Discovery operation bits are used to query and manipulate the Remote Discovery Register.

The default state of these bits is "Ready." The bits indicate "Ready" any time the PMI Aggregation function is capable of performing an operation on the Remote Discovery Register.

If the STA sets the bits to "Get," the PMI Aggregation function querys the Remote Discovery Register and return its contents to the Aggregation Discovery Code register.

If the STA sets the bits to "Set if clear," the PMI Aggregation function passes a message to the "-R" PCS instructing it to set the Remote Discovery Register to the contents of the Aggregation Discovery Code register, but only if the Remote Discovery Register is clear (0x000000000000)

If the STA sets the bits to "Clear if same," the PMI Aggregation function passes a message to the "-R" PCS instructing it to clear the Remote Discovery Register, but only if the contents of the Remote Discovery Register currently match the contents of the Aggregation Discovery Code register.

While the requested operation is in progress, the PHY maintains the operation value in the bits. After the operation is complete, the PHY sets the bits to indicate "Ready"

45.2.4.3.2 Discovery operation result (3.x.13)

When a discovery operation is complete, the PHY sets this bit to indicate the result of the operation. A "1" indicates that the operation could not be completed. This may be for a variety of reasons:

a) link is down
b) a "Set if clear" operation was requested but the Remote Discovery Register was not clear
c) a "Clear if same" operation was requested but the Remote Discovery Register did not match the Aggregation Discovery Code register.
d) ***Editor's Note:*** *what else?*

45.2.4.4 Aggregation Discovery Code register

The Aggregation Discovery Code register stores the code used by the PMI Aggregation discovery mechanism.

This register is defined only for “-O” ports.

The Aggregation Discovery Code register shall be implemented as a unique register for each PCS MMDs in a package. For example, a package implementing four EFM Cu PHYs would have four independent instances of the Aggregation Discovery Code register, accessed by a read or write to 3.50 to each PHY

The assignment of bits for the Aggregation Discovery Code register is shown in Table 45–8.

Table 45–8—Aggregation Discovery Code register bit definitions

Bit(s)	Name	Description	R/W
3.50.15:0	Code[47:32]	The two high order octets of the Aggregation Discovery Code	R/W[a]
3.51.15:0	Code[31:16]	The two middle octets of the Aggregation Discovery Code	R/W
3.52.15:0	Code[15:0]	The two low order octets of the Aggregation Discovery Code	R/W

[a]RW = Read/Write

45.2.4.5 PAF RX error register

The PAF RX error register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface with RxErr asserted. These bits shall be reset to all zeroes when the PAF RX error register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the PAF RX error register is shown in Table 45–9.

Table 45–9—PAF RX error register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	PAF RX errors[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.2.4.6 PAF small fragments register

The PAF small fragments register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface which were smaller than the minFragmentSize defined in **REFERENCE**. These bits shall be reset to all zeroes when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the PAF small fragment register is shown in Table 45–10.

Table 45–10—PAF small fragments register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	PAF small fragments[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.2.4.7 PAF large fragments register

The PAF large fragments register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface which were larger than the maxFragmentSize defined in **REFERENCE**. These bits shall be reset to all zeroes when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the PAF large fragments register is shown in Table 45–11.

Table 45–11—PAF large fragments register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	PAF large fragments[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.2.4.8 PAF overflow register

The PAF overflow register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface which would have caused the receive buffer to overflow. These bits shall be reset to all zeroes when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the PAF overflow register is shown in Table 45–12.

Table 45–12—PAF overflow register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	PAF overflow fragments[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.2.4.9 PAF bad fragment register

The PAF bad fragment register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface which did not fit into the sequence expected by the frame assembly function. These bits shall be reset to all zeroes when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the PAF bad fragment register is shown in Table 45–13.

Table 45–13—PAF bad fragment register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	PAF bad fragments[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.2.4.10 PAF lost fragment register

The PAF lost fragment register is a 16 bit counter that contains the number of gaps in the sequence of fragments expected by the frame assembly function that have been received across the gamma interface. These bits shall be reset to all zeroes when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the PAF lost fragment register is shown in Table 45–14.

Table 45–14—PAF lost fragment register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	PAF lost fragments[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.2.5 EFM Cu PCS TPS-TC registers

The following registers pertain to the encapsulation function of the EFM Cu TPS-TC. See (see 61.2.3)

45.2.5.1 TPS-TC Status register

The TPS-TC Status register conveys fault information from the TPS-TC encapsulation function. The assignment of bits in the TPS-TC Status register is show in Table 45–15.

Table 45–15—TPS-TC Status register bit definitions

Bit(s)	Name	Description	R/W
3.x.15	TPS-TC sync lost	Defaults to 0. Set to 1 when the synchronization state machine has detected a corrupted sync code and is free-wheeling.	RO[a], LH[b]
3.x.13:0	reserved	Value always 0, writes ignored	R/W

[a]RO = Read Only
[b]LH = Latches High

45.2.5.1.1 TPS-TC sync lost (3.x.15)

(See 61.2.3.3.6)

45.2.5.2 TPS-TC CRC Error register

The TPS-TC CRC Error register is a 16 bit counter that contains the number TPS-TC frames received with the TC_CRC_error primitive asserted (see 61.2.3.3.6). These bits shall be reset to all zeroes when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the TPS-TC CRC Error register are shown in Table 45–16.

Table 45–16—TPS-TC CRC Error register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	CRC Errors[15:0]	The bytes of the counter	RO[a], CR[b]

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.3 EFM Cu PMA/PMD Registers for Clause 62, common to SCM and MCM

45.3.1 PMA/PMD Registers

45.3.1.1 PMA/PMD Control register

The assignment of bits in the PMA Control register is shown in Table 45–17.

Table 45–17—PMA Control register bit definitions

Bit(s)	Name	Description	R/W
1.x.15	Generate FEC errors	1 = RS encoder transmits invalid codewords 0 = RS encoder functions normally (default)	O: R/W[a] R: RO[b]
1.x.14:12	PMA/PMD type selection	2 1 0 0 0 0 = 10PASS-TS PMA/PMD type 0 0 1 = 2BASE-TL PMA/PMD type all other values are reserved	O: R/W R: R/W
1.x.11:0	reserved	Value always 0, writes ignored	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

45.3.1.2 Generate FEC errors (1.x.15)

TBD

45.3.1.3 PMA/PMD type selection (1.x.14:12)

The PMA/PMD type of the EFM Cu PHY may be selected using bits 14 through 12. A 10G PMA/PMD may ignore writes to the PMA/PMD type selection bits that select PMA/PMD types it has not advertised in the status register. **Ed's note: We need to add such a status register** It is the responsibility of the STA entity to ensure that mutually acceptable MMD types are applied consistently across all the MMDs on a particular PHY.

The selection is advertised during link initialization G.994 handshake.

The PMA/PMD type selection defaults to a supported ability.

ED NOTE: Need some way of getting this setting across the link during handshake

45.3.1.4 Remote PMA Control register

The assignment of bits in the PMA Control register is shown in Table 45–18. This register is defined only for "-O" ports.

Table 45–18—Remote PMA Control Register

Bit(s)	Name	Description	R/W
1.x.15	Generate FEC errors	1 = RS encoder transmits invalid codewords 0 = RS encoder functions normally (default)	O: R/W[a], N[b] R: undefined
1.x.14:0	reserved	Value always 0, writes ignored	O: R/W R: undefined

[a]RW = Read/Write
[b]changing this register takes immediate effect on the "-R" link partner

45.3.1.4.1 Generate FEC errors (1.x.15)

TBD

45.3.1.5 FEC Correctable Errors register

The FEC Correctable Errors register is a 32 bit counter that contains the number of FEC codewords that have been received and corrected. These bits shall be reset to all zeroes when the FEC Correctable Errors register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the FEC Correctable Error register is shown in Table 45–19.

Table 45–19—FEC Correctable Errors register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	Correctable codewords [31:16]	The high order bytes of the counter	RO[a], CR[b]
1.x+1.15:0	Correctable codewords [15:0]	The low order bytes of the counter	RO, CR

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.3.1.6 FEC Uncorrectable Errors register

The FEC Uncorrectable Errors register is a 32 bit counter that contains the number of FEC codewords that have been received and are uncorrectable. These bits shall be reset to all zeroes when the FEC Uncorrectable Errors register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the FEC Uncorrectable Error register is shown in Table 45–20.

Table 45–20—FEC Uncorrectable Errors register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	Uncorrectable codewords [31:16]	The high order bytes of the counter	RO[a], CR[b]
1.x+1.15:0	Uncorrectable codewords [15:0]	The low order bytes of the counter	RO, CR

[a]RO = Read Only
[b]indicates that the register clears itself when read

45.3.1.7 Electrical Length register

The bit definitions for the Electrical Length register are found in Table 45–21.

Table 45–21—Electrical Length register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	Electrical Length	The electrical length of the medium (in meters), as perceived at the local PMD	O: RO[a] R: RO

[a]RO = Read Only

45.3.1.7.1 Electrical Length (1.x.15:0)

TBD

45.3.1.8 Remote Electrical Length register

The bit definitions for the Electrical Length register are found in Table 45–22.

Table 45–22—Remote Electrical Length register bit definitions

Bits(s)	Name	Description	R/W
1.x.15:0	Electrical Length	The electrical length of the medium (in meters), as perceived at the “-R” link partner	O: RO[a] R: undefined

[a]RO = Read Only

This register is defined only for “-O” port types.

45.3.1.8.1 Electrical Length (1.x.15:0)

45.3.1.9 TBD

45.4 PMA/PMD Registers for Clause 62, SCM version

45.4.1 PMD Registers

45.4.1.1 Remote Parameter Activate register

The bits in this register activate the parameters set in their respective registers. A write to multiple bits in this register shall atomically activate all parameters associated with the set bits. Each bit clears itself upon completion of the activation. The bit definitions for the PSD Limit register are found in Table 45–23

This register is only defined for “-O” port types.

Table 45–23—Remote Parameter Activate register bit definitions

Bit(s)	Name	Description	R/W
1.x.15	Activate PSD limits	1 = activate the settings in the Remote PSD Limit register 0 = ready, operation complete	O: R/W[a], SC[b] R: undefined
1.x.14	Activate TX symbol rate	1 = activate the settings in the Remote TX Symbol Rate register 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.13	Activate RX symbol rate	1 = activate the settings in the Remote RX Symbol Rate register 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.12	Activate TX constellation	1 = activate the settings in the Remote Constellation register bits [15:8] 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.11	Activate RX constellation	1 = activate the settings in the Remote Constellation register bits [7:0] 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.10	Activate TX center frequency	1 = activate the settings in the Remote TX Center frequency register 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.9	Activate RX center frequency	1 = activate the settings in the Remote RX Center frequency register 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.8	Activate TX PSD level	1 = activate the settings in the Remote TX PSD level register 0 = ready, operation complete	O: R/W, SC R: undefined
1.x.7:0	reserved	Value always 0, writes ignored	O: R/W, SC R: undefined

[a]RW = Read/Write
[b]self-clearing

45.4.1.1.1 Activate PSD limits (1.x.15)

TBD

45.4.1.1.2 Activate TX symbol rate (1.x.14)

TBD

45.4.1.1.3 Activate RX symbol rate bit (1.x.13)

TBD

45.4.1.1.4 Activate TX constellation (1.x.12)

TBD

45.4.1.1.5 Activate RX constellation (1.x.11)

TBD

45.4.1.1.6 Activate TX center frequency (1.x.10)

TBD

45.4.1.1.7 Activate RX center frequency (1.x.9)

TBD

45.4.1.1.8 Activate TX PSD level bit definition (1.x.8)

TBD

45.4.1.2 Interleaver Control register

The Interleaver Control register is used to set variables for the PMA interleaver function. (See 62.3.2.2.9)

For "-O" ports, this register is read/write and sets the local transmit and receive interleaver variables. For "-R" ports, this register is read-only and reports the settings of the transmit and receive interleaver, as set by the "-O" link partner.

For a properly functioning link, the "-O" and "-R" interleaver variables must both be set to the same values. See the Remote Interleaver Control register (45.4.1.3) for the mechanism to set the variables on the "-R" link partner

The bit definitions for the Interleaver Control register can be found in Table 45–24

45.4.1.3 Remote Interleaver Control register

The Remote Interleaver Control register is used to set variables for the "-R" link partner's PMA interleaver function. (See 62.3.2.2.9)

For "-O" ports, this register is read/write and sets the link partner transmit and receive interleaver variables. this register is not defined for "-R" ports. "-R" STAs may use the Interleaver Control register (45.4.1.2) to observe the variables as set by the "-O" link partner.

The bit definitions for the Remote Interleaver Control register can be found in Table 45–25

45.4.1.4 PSD Limit register

The bit definitions for the PSD Limit register are found in Table 45–26.

Table 45–24—Interleaver Control register bit definition

Bit(s)	Name	Description	R/W
1.x.15:12	reserved	Value always 0, writes ignored	O: R/W[a] R: RO[b]
1.x.11:10	DS interleaver block size	00 = DS interleaver deactivated 01 = DS interleaver block size = 100 10 = DS interleaver block size = 50 11 = DS interleaver block size = 25	O: R/W R: RO
1.x.10:8	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x.7:0	DS interleaver depth	M := value of bits M = 0, invalid, write ignored M > 0, DS interleaver depth is M	O: R/W R: RO
1.x+1.15:12	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+1.11:10	US interleaver block size	00 = US interleaver deactivated 01 = US interleaver block size = 100 10 = US interleaver block size = 50 11 = US interleaver block size = 25	O: R/W R: RO
1.x+1.10:8	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+1.7:0	US interleaver depth	M := value of bits M = 0, invalid, write ignored M > 0, DS interleaver depth is M	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

45.4.1.4.1 PSD Boost (1.x.10:11)

TBD

45.4.1.4.2 Mask (1.x.9)

TBD

45.4.1.4.3 reserved (1.x.8)

TBD

45.4.1.4.4 Notch 1 (1.x.5)

TBD

45.4.1.4.5 Notch 2 (1.x.4)

TBD

Table 45–25—Remote Interleaver Control register bit definition

Bit(s)	Name	Description	R/W
1.x.15:12	reserved	Value always 0, writes ignored	O: R/W[a] R: undefined
1.x.11:10	DS interleaver block size	00 = DS interleaver deactivated 01 = DS interleaver block size = 100 10 = DS interleaver block size = 50 11 = DS interleaver block size = 25	O: R/W R: undefined
1.x.10:8	reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x.7:0	DS interleaver depth	M := value of bits M = 0, invalid, write ignored M > 0, DS interleaver depth is M	O: R/W R: undefined
1.x+1.15:12	reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+1.11:10	US interleaver block size	00 = US interleaver deactivated 01 = US interleaver block size = 100 10 = US interleaver block size = 50 11 = US interleaver block size = 25	O: R/W R: undefined
1.x+1.10:8	reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+1.7:0	US interleaver depth	M := value of bits M = 0, invalid, write ignored M > 0, DS interleaver depth is M	O: R/W R: undefined

[a]RW = Read/Write

45.4.1.4.6 Notch 3 (1.x.3)

TBD

45.4.1.4.7 Notch 4 (1.x.2)

TBD

45.4.1.4.8 Notch 5 (1.x.1)

TBD

45.4.1.4.9 Notch 6 (1.x.0)

TBD

45.4.1.5 Remote PSD Limit register

The bit definitions for the Remote PSD Limit register are found in Table 45–27. This register is defined only for “-O” port types.

Table 45–26—PSD Limit register bit definitions

Bit(s)	Name	Description	R/W
1.x.15:12	reserved	Value always 0, writes ignored	O: R/W[a] R: RO[b]
1.x.11:10	PSD Boost	Controls boost of TX PSD 00 = no boost (default) 01 = boost 3 dBm/Hz 10 = boost 6 dBm/Hz 11 = boost 9 dBm/Hz	O: R/W R: RO
1.x.9	Mask	0 = M1 (default) 1 = M2 **Editor's Note:** What are these and what do they do?	O: R/W R: RO
1.x.8:6	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x.5	Notch 1	Notch TX in amateur radio band 1 0 = notch off (default) 1 = notch on	O: R/W R: RO
1.x.4	Notch 2	Notch TX in amateur radio band 2 0 = notch off (default) 1 = notch on	O: R/W R: RO
1.x.3	Notch 3	Notch TX in amateur radio band 3 0 = notch off (default) 1 = notch on	O: R/W R: RO
1.x.2	Notch 4	Notch TX in amateur radio band 4 0 = notch off (default) 1 = notch on	O: R/W R: RO
1.x.1	Notch 5	Notch TX in amateur radio band 5 0 = notch off (default) 1 = notch on	O: R/W R: RO
1.x.0	Notch 6	Notch TX in amateur radio band 6 0 = notch off (default) 1 = notch on	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

45.4.1.5.1 PSD Boost (1.x.10:11)

TBD

45.4.1.5.2 Mask (1.x.9)

TBD

45.4.1.5.3 reserved (1.x.8)

TBD

Table 45–27—Remote PSD Limit register

Bit(s)	Name	Description	R/W
1.x.15:12	reserved	Value always 0, writes ignored	O: R/W[a] R: undefined
1.x.11:10	PSD Boost	Controls boost of TX PSD 00 = no boost (default) 01 = boost 3 dBm/Hz 10 = boost 6 dBm/Hz 11 = boost 9 dBm/Hz	O: R/W, D[b] R: undefined
1.x.9	Mask	0 = M1 (default) 1 = M2 **Editor's Note:** What are these and what do they do?	O: R/W, D R: undefined
1.x.8:6	reserved	Value always 0, writes ignored	O: R/W, D R: undefined
1.x.5	Notch 1	Notch TX in amateur radio band 1 0 = notch off (default) 1 = notch on	O: R/W, D R: undefined
1.x.4	Notch 2	Notch TX in amateur radio band 2 0 = notch off (default) 1 = notch on	O: R/W, D R: undefined
1.x.3	Notch 3	Notch TX in amateur radio band 3 0 = notch off (default) 1 = notch on	O: R/W, D R: undefined
1.x.2	Notch 4	Notch TX in amateur radio band 4 0 = notch off (default) 1 = notch on	O: R/W, D R: undefined
1.x.1	Notch 5	Notch TX in amateur radio band 5 0 = notch off (default) 1 = notch on	O: R/W, D R: undefined
1.x.0	Notch 6	Notch TX in amateur radio band 6 0 = notch off (default) 1 = notch on	O: R/W, D R: undefined

[a]RW = Read/Write
[b]D = the "-R" link partner is set only when appropriate activate register bit is set

45.4.1.5.4 Notch 1 (1.x.5)

TBD

45.4.1.5.5 Notch 2 (1.x.4)

TBD

45.4.1.5.6 Notch 3 (1.x.3)

TBD

45.4.1.5.7 Notch 4 (1.x.2)

TBD

45.4.1.5.8 Notch 5 (1.x.1)

TBD

45.4.1.5.9 Notch 6 (1.x.0)

TBD

45.4.1.6 Frame Configuration register

Editor's Note: *Assuming we will pick a fixed frame format, this register is not necessary*

45.4.1.7 Symbol Rate register

The bit definitions for the Symbol Rate register are found in Table 45–20.

Table 45–28—Symbol Rate register bit definition

Bit(s)	Name	Description	R/W
1.x.15:10	Reserved	Value always 0, writes ignored	O: R/W[a] R: RO[b]
1.x.9:0	DS carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W R: RO
1.x+1.15:10	Reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+1.9:0	DS carrier 2 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W R: RO
1.x+2.15:10	Reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+2.9:0	US carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W R: RO
1.x+3.15:10	Reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+3.9:0	US carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

45.4.1.7.1 DS carrier 1 Symbol rate(1.x.9:0)

TBD

45.4.1.7.2 DS carrier 2 Symbol rate(1.x+1.9:0)

TBD

45.4.1.7.3 US carrier 1 Symbol rate(1.x+2.9:0)

TBD

45.4.1.7.4 US carrier 2 Symbol rate (1.x+3.9:0)

TBD

45.4.1.8 Remote Symbol Rate register

The bit definitions for the Remote Symbol Rate register are found in Table 45–29. This register is defined only for “-O” ports.

Table 45–29—Remote Symbol Rate register bit definition

Bit(s)	Name	Description	R/W
1.x.15:10	Reserved	Value always 0, writes ignored	O: R/W[a] R: undefined
1.x.9:0	DS carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W, D[b] R: undefined
1.x+1.15:10	Reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+1.9:0	DS carrier 2 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W, D R: undefined
1.x+2.15:10	Reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+2.9:0	US carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W, D R: undefined
1.x+3.15:10	Reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+3.9:0	US carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: R/W, D R: undefined

[a]RW = Read/Write
[b]D = the “-R” link partner is set only when appropriate activate register bit is set

45.4.1.8.1 DS carrier 1 Symbol rate(1.x.9:0)

TBD

45.4.1.8.2 DS carrier 2 Symbol rate(1.x+1.9:0)

TBD

45.4.1.8.3 US carrier 1 Symbol rate(1.x+2.9:0)

TBD

45.4.1.8.4 US carrier 2 Symbol rate (1.x+3.9:0)

TBD

45.4.1.9 Constellation register

The bit definitions for the Constellation register are found in Table 45–30.

Table 45–30—Constellation register bit definition

Bit(s)	Name	Description	R/W
1.x.15:12	DS carrier 1 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W[a] R: RO[b]
1.x.11:8	DS carrier 2 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W R: RO
1.x.7:4	US carrier 1 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W R: RO
1.x.3:0	US carrier 2 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

45.4.1.9.1 DS carrier 1 constellation (1.x.15:12)

TBD

45.4.1.9.2 DS carrier 2 constellation (1.x.11:8)

TBD

45.4.1.9.3 US carrier 1 constellation (1.x.7:4)

TBD

45.4.1.9.4 US carrier 2 constellation(1.x.3:0)

TBD

45.4.1.10 Remote Constellation register

The bit definitions for the Remote Constellation register are found in Table 45–31. This register is defined only for "-O" ports.

Table 45–31—Remote Constellation register bit definition

Bit(s)	Name	Description	R/W
1.x.15:12	DS carrier 1 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W[a], D[b] R: undefined
1.x.11:8	DS carrier 2 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W, D R: undefined
1.x.7:4	US carrier 1 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W, D R: undefined
1.x.3:0	US carrier 2 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: R/W, D R: undefined

[a]RW = Read/Write
[b]D = the "-R" link partner is set only when appropriate activate register bit is set

45.4.1.10.1 DS carrier 1 constellation (1.x.15:12)

TBD

45.4.1.10.2 DS carrier 2 constellation (1.x.11:8)

TBD

45.4.1.10.3 US carrier 1 constellation (1.x.7:4)

TBD

45.4.1.10.4 US carrier 2 constellation(1.x.3:0)

TBD

45.4.1.11 Center Frequency register

The bit definitions for the Center Frequency register are found in Table 45–25.

45.4.1.11.1 DS carrier 1 center frequency (1.x.10:0)

TBD

Table 45–32—Center Frequency register bit definition

Bit(s)	Name	Description	R/W
1.x.15:11	reserved	Value always 0, writes ignored	O: R/W[a] R: RO[b]
1.x.10:0	DS carrier 1 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W R: RO
1.x+1.15:11	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+1.10:0	DS carrier 2 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W R: RO
1.x+2.15:11	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+2.10:0	US carrier 1 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W R: RO
1.x+3.15:11	reserved	Value always 0, writes ignored	O: R/W R: RO
1.x+3.10:0	US carrier 2 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

45.4.1.11.2 DS carrier 2 center frequency (1.x+1.10:0)

TBD

45.4.1.11.3 US carrier 1 center frequency (1.x+2.10:0)

TBD

45.4.1.11.4 US carrier 2 center frequency (1.x+3.10:0)

TBD

45.4.1.12 Remote Center Frequency register

The bit definitions for the Remote Center Frequency register are found in Table 45–33. This register is defined only for “-O” ports.

45.4.1.12.1 DS carrier 1 center frequency (1.x.10:0)

TBD

45.4.1.12.2 DS carrier 2 center frequency (1.x+1.10:0)

TBD

Table 45–33—Remote Center Frequency register bit definition

Bit(s)	Name	Description	R/W
1.x.15:11	reserved	Value always 0, writes ignored	O: R/W[a] R: undefined
1.x.10:0	DS carrier 1 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W, D[b] R: undefined
1.x+1.15:11	reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+1.10:0	DS carrier 2 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W, D R: undefined
1.x+2.15:11	reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+2.10:0	US carrier 1 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W, D R: undefined
1.x+3.15:11	reserved	Value always 0, writes ignored	O: R/W R: undefined
1.x+3.10:0	US carrier 2 center frequency	F := value of bits center frequency = 16875 * F Hz	O: R/W, D R: undefined

[a]RW = Read/Write
[b]D = the “-R” link partner is set only when appropriate activate register bit is set

45.4.1.12.3 US carrier 1 center frequency (1.x+2.10:0)

TBD

45.4.1.12.4 US carrier 2 center frequency (1.x+3.10:0)

TBD

45.4.1.13 TX PSD Level register

The TX PSD Level register is used to control the power level at which the PMD transmits. (See 62.5.4.1.2)

For “-O” ports, this register is read/write and sets the local transmit PSD level. For “-R” ports, this register is read-only and reports the settings of the transmit PSD level, as set by the “-O” link partner.

ED NOTE: What do the US bits in this register do?!?!

The bit definitions for the TX PSD level register are found in Table 45–34.

45.4.1.14 Remote TX PSD Level register

The bit definitions for the Remote TX PSD level register are found in Table 45–35.

For “-O” ports, this register is read/write and sets the “-R” link partner’s transmit PSD level.

ED NOTE: What is the read behavior? Also, what is the behavior of the DS bits?

Table 45–34—TX PSD level register bit definition

Bit(s)	Name	Description	R/W
1.x.15:9	reserved	value always 0, writes ignored	O: R/W[a] R: RO[b]
1.x.8:0	DS carrier 1 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W R: RO
1.x+1:15:9	reserved	value always 0, writes ignored	O: R/W R: RO
1.x+1.8:0	DS carrier 2 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W R: RO
1.x+2.15:9	reserved	value always 0, writes ignored	O: R/W R: RO
1.x+2.8:0	US carrier 1 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W R: RO
1.x+3:15:9	reserved	value always 0, writes ignored	O: R/W R: RO
1.x+3.8:0	US carrier 2 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W R: RO

[a]RW = Read/Write
[b]RO = Read Only

This register is defined only for "-O" ports.

Table 45–35—Remote TX PSD level register bit definition

Bit(s)	Name	Description	R/W
1.x.15:9	reserved	value always 0, writes ignored	O: R/W[a] R: undefined
1.x.8:0	DS carrier 1 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W, D[b] R: undefined
1.x+1:15:9	reserved	value always 0, writes ignored	O: R/W R: undefined
1.x+1.8:0	DS carrier 2 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W, D R: undefined
1.x+2.15:9	reserved	value always 0, writes ignored	O: R/W R: undefined
1.x+2.8:0	US carrier 1 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W, D R: undefined
1.x+3:15:9	reserved	value always 0, writes ignored	O: R/W R: undefined
1.x+3.8:0	US carrier 2 PSD level	P := value of bits (2's complement) PSD Level = P/4 + 100 dBm/Hz	O: R/W, D R: RO

[a]RW = Read/Write
[b]D = the "-R" link partner is set only when appropriate activate register bit is set

45.4.1.14.1 US carrier 1 PSD level (1.x.15:8)

TBD

45.4.1.14.2 US carrier 2 PSD level (1.x.7:0)

TBD

45.4.1.15 Recommended Symbol Rate register

The bit definitions for the Recommended Symbol Rate register are found in Table 45–36. This register is defined only for the "-R" ports.

Table 45–36—Recommended Symbol Rate register bit definition

Bit(s)	Name	Description	R/W
1.x.15:10	Reserved	Value always 0, writes ignored	O: undefined R: R/W[a]
1.x.9:0	Recommended DS carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: undefined R: R/W
1.x+1.15:10	Reserved	Value always 0, writes ignored	O: undefined R: R/W
1.x+1.9:0	Recommended DS carrier 2 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: undefined R: R/W

[a]R/W = Read/Write

45.4.1.15.1 Recommended DS carrier 1 Symbol Rate (1.x.15:9)

TBD

45.4.1.15.2 Recommended DS carrier 2 Symbol Rate (1.x+1.15:9)

TBD

45.4.1.16 Recommended Center Frequency register

The bit definitions for the Center Frequency register are found in Table 45–37. This register is defined only for the "-R" ports

45.4.1.16.1 Recommended DS carrier 1 center frequency (1.x.10:0)

TBD

45.4.1.16.2 Recommended DS carrier 2 center frequency (1.x+1.10:0)

TBD

Table 45–37—Recommended Center Frequency register bit definition

Bit(s)	Name	Description	R/W
1.x.15:11	reserved	Value always 0, writes ignored	O: undefined R:R/W[a]
1.x.10:0	Recommended DS carrier 1 center frequency	F := value of bits center frequency = 16875 * F Hz	O: undefined R:R/W
1.x+1.15:11	reserved	Value always 0, writes ignored	O: undefined R:R/W
1.x+1.10:0	Recommended DS carrier 2 center frequency	F := value of bits center frequency = 16875 * F Hz	O: undefined R:R/W

[a]R/W = Read/Write

45.4.1.17 Recommended Constellation register

The bit definitions for the Recommended Constellation register are found in Table 45–38. This register is defined only for the "-R" ports.

Table 45–38—Recommended Constellation register bit definition

Bit(s)	Name	Description	R/W
1.x.15:12	Recommended DS carrier 1 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: undefined R: R/W[a]
1.x.11:8	Recommended DS carrier 2 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: undefined R: R/W
1.x.7:0	reserved	Value always 0, writes ignored	O: undefined R: R/W

[a]R/W = Read/Write

45.4.1.17.1 Recommended DS carrier 1 constellation (1.x.15:12)

TBD

45.4.1.17.2 Recommended DS carrier 2 constellation (1.x.11:8)

TBD

45.4.1.18 Remote Recommended Symbol Rate register

The bit definitions for the Remote Recommended Symbol Rate register are found inTable 45–39. This register is defined only for "-O" ports.

Table 45–39—Remote Recommended Symbol Rate register bit definition

Bit(s)	Name	Description	R/W
1.x.15:10	Reserved	Value always 0, writes ignored	O: RO[a] R: undefined
1.x.9:0	Recommended DS carrier 1 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: RO R: undefined
1.x+1.15:10	Reserved	Value always 0, writes ignored	O: RO R: undefined
1.x+1.9:0	Recommended DS carrier 2 Symbol rate	S := value of bits symbol rate = 16875 * S baud/sec	O: RO R: undefined

[a]RO = Read Only

45.4.1.18.1 Recommended DS carrier 1 Symbol Rate (1.x.15:9)

TBD

45.4.1.18.2 Recommended DS carrier 2 Symbol Rate (1.x+1.15:9)

TBD

45.4.1.19 Remote Recommended Center Frequency register

The bit definitions for the Center Frequency register are found in Table 45–40. This register is defined only for “-O” ports

Table 45–40—Remote Recommended Center Frequency register bit definition

Bit(s)	Name	Description	R/W
1.x.15:11	reserved	Value always 0, writes ignored	O: RO[a] R: undefined
1.x.10:0	Recommended DS carrier 1 center frequency	F := value of bits center frequency = 16875 * F Hz	O: RO R: undefined
1.x+1.15:11	reserved	Value always 0, writes ignored	O: RO R: undefined
1.x+1.10:0	Recommended DS carrier 2 center frequency	F := value of bits center frequency = 16875 * F Hz	O: RO R: undefined

[a]RO = Read Only

45.4.1.19.1 Recommended DS carrier 1 center frequency (1.x.10:0)

TBD

45.4.1.19.2 Recommended DS carrier 2 center frequency (1.x+1.10:0)

TBD

45.4.1.20 Remote Recommended Constellation register

The bit definitions for the Remote Recommended Constellation register are found in Table 45–41. This register is defined only for “-O” ports.

Table 45–41—Remote Recommended Constellation register bit definition

Bit(s)	Name	Description	R/W
1.x.15:12	Recommended DS carrier 1 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: RO[a] R: undefined
1.x.11:8	Recommended DS carrier 2 constellation	C := value of bits constellation size = 2^C C = 0 is invalid C > 10 is invalid	O: RO R: undefined
1.x.7:0	reserved	Value always 0, writes ignored	O: RO R: undefined

[a]RO = Read Only

45.4.1.20.1 Recommended DS carrier 1 constellation (1.x.15:12)

TBD

45.4.1.20.2 Recommended DS carrier 2 constellation (1.x.11:8)

TBD

45.4.1.21 RX SNR

The bit definitions for the RX SNR register are found in Table 45–42.

Table 45–42—RX SNR register bit definition

Bit(s)	Name	Description	R/W
1.x.15:8	RX carrier 1 SNR	S := value of bits SNR = S/4	O: RO[a] R: RO
1.x.7:0	RX carrier 2 SNR	S := value of bits SNR =S/4	O: RO R: RO

[a]RO = Read Only

45.4.1.21.1 RX carrier 1 SNR (1.x.15:8)

TBD

45.4.1.21.2 RX carrier 2 SNR (1.x.7:0)

TBD

45.4.1.22 Line Attenuation register

The Line Attenuation register reports the attenuation for each carrier in the link. See **(reference required)** for details on the measurement and communication of line attenuation on the link. The bit definitions for the Line Attenuation register are shown in Table 45–43

Table 45–43—Line Attenuation register bit definition

Bit(s)	Name	Description	R/W
1.x.15:9	reserved	Value always 0	O: RO[a] R: RO
1.x.8:0	DS carrier 1 line attenuation	A := value of bits attenuation = A/4 (in dB)	O: RO R: RO
1.x+1.15:9	reserved	Value always 0	O: RO R: RO
1.x+1.8:0	DS carrier 2 line attenuation	A := value of bits attenuation = A/4 (in dB)	O: RO R: RO
1.x+2.15:9	reserved	Value always 0	O: RO R: RO
1.x+2.8:0	US carrier 1 line attenuation	A := value of bits attenuation = A/4 (in dB)	O: RO R: RO
1.x+3.15:9	reserved	Value always 0	O: RO R: RO
1.x+3.8:0	US carrier 2 line attenuation	A := value of bits attenuation = A/4 (in dB)	O: RO R: RO

[a]RO = Read Only

45.4.1.23 Indicator Bits Status register

The Indicator Bits Status register conveys the current state of the indicator bits being sent over the link by the local PMA and received on the link from the remote PMA. (See 62.3.2) The bit definitions for the Indicator Bits Status register are shown in Table 45–44

45.5 PMA/PMD Registers for Clause 62, MCM version

45.5.1 PMD registers

45.5.1.1 Overview

MCM operates by modulating 4098 individual tones across the transmission spectrum. Each tone can be assigned a PSD level, desired SNR margin and transmission direction (downstream or upstream). To reduce

Table 45–44—Indicator Bits Status register bit definition

Bit(s)	Name	Description	R/W
1.x.15	*trig*	O: the state of the *r_trig* primitive R: the state of the *o_trig* primitive 0 = primitive not asserted 1 = primitive asserted	O: RO[a] R: RO
1.x.14	*flag*	O: the state of the *r_flag* primitive R: the state of the *o_flag* primitive 0 = primitive not asserted 1 = primitive asserted	O: RO R: RO
1.x.13	IB-1 (*fp_1)*	Far-end TPS_TC defect/failure #1 0 = primitive not asserted 1 = primitive asserted	O: RO R: RO
1.x.12	IB-2 (*fp_2)*	Far-end TPS_TC defect/failure #2 0 = primitive not asserted 1 = primitive asserted	O: RO R: RO
1.x.11	IB-3 (*fp_3)*	Far-end TPS_TC defect/failure #3 0 = primitive not asserted 1 = primitive asserted	O: RO R: RO
1.x.10	IB-4 (*fp_4)*	Far-end TPS_TC defect/failure #4 0 = primitive not asserted 1 = primitive asserted	O: RO R: RO
1.x.9	IB-5 *(reserved)*	0 = normal state 1 = reserved condition	O: RO R: RO
1.x.8	NTR	reserved and out of scope (See T1.424/Trial-Use standard Part 1)	O: RO R: RO
1.x.7	IB-6 (*reserved*)	0 = normal state 1 = reserved condition	O: RO R: RO
1.x.6	IB-7 *(flos_cr1)*	0 = normal state 1 = link partner is reporting loss of carrier 1	O: RO R: RO

Table 45–44—Indicator Bits Status register bit definition

Bit(s)	Name	Description	R/W
1.x.5	IB-8 *(flos_cr2)*	0 = normal state 1 = link partner is reporting loss of carrier 2	O: RO R: RO
1.x.4	IB-9 *(rdi)*	0 = normal state 1 = link partner is reporting the reception of a severely errored PMA frame	O: RO R: RO
1.x.3	IB-10 *(reserved)*	0 = normal state 1 = reserved condition	O: RO R: RO
1.x.2	IB-11 *(reserved)*	0 = normal state 1 = reserved condition	O: RO R: RO
1.x.1	reserved	value always 0	O: RO R: RO
1.x+1.15	reserved	value always 0	O: RO R: RO
1.x+1.14	IB-12 *(FPO)*	0 = normal state 1 = link partner is reporting a Power-off failure	O: RO R: RO
1.x+1.13	IB-13 *(flpr)*	0 = normal state 1 = link partner is reporting a Loss-of-Power defect (dying gasp)	O: RO R: RO
1.x+1.12:9	proprietary	reserved for proprietary application 0 = normal state 1 = unspecified condition	O: RO R: RO
1.x+1.8:0		value always 0	O: RO R: RO

[a]RO = Read Only

the complexity of addressing individual tones, tones are addressed by group. The STA sets the lower and upper tones in a group, sets the parameters for that group, and issues a command to activate those parameters for that group. See Clause 62 (MCM) for details on the mechanism that transfers tone information across the link to and from the "-R" link partner.

Additionally, there is defined an MDIO Manageable Device at address 6, the Tone Table. The Tone Table is used to query the status of every tone in the PMD.

Editor's Note: Must update Table 45-1 to reflect the new MMD.

45.5.1.2 Tone Group register

Table 45–45—Tone Group register bit definitions

Bit(s)	Name	Description	R/W
1.x.15:0	Lower tone	The number of the lower frequency tone in the group. Valid when <= the Upper tone.	R/W[a]
1.x+1.15:0	Upper tone	The number of the higher frequency tone in the group. Valid when >= the Lower tone.	R/W

[a]RW = Read/Write

This register allows the STA to specify the range of tones to control. The bit definitions for the Tone Group register are defined in Table 45–45. This register is defined only for "-O" ports.

45.5.1.3 Tone Control Parameter register

Table 45–46—Tone Control Parameter Register

Bit(s)	Name	Description	R/W
1.x.15	Tone active	0 = selected tones are disabled 1 = selected tones are active	R/W[a]
1.x.14	Tone direction	0 = selected tones are assigned for DS communication 1 = selected tones are assigned for US communication	R/W
1.x.13:5	Max SNR margin	Assigns the maximum SNR margin the tones shall achieve M := value of bits Max SNR Margin = M/4 dB	R/W
1.x.4:0, 1.x+1.15:12	Min SNR margin	Assigns a target SNR margin for the selected tones M := value of bits Min SNR Margin = M/4 dB	R/W
1.x+1.11:8	reserved	value always 0, writes ignored	R/W
1.x+1.7:0	PSD level	Assigns a TX PSD level for the selected tones in dBm/Hz	R/W

[a]RW = Read/Write

This register allows the STA to specify values for various parameters for the tones selected in the Tone Group register. These values do not take effect until the corresponding activation commands are issued in the Tone Control Action register. The bit definitions for the Tone Control Action register are shown in Table 45–46. This register is defined for only "-O" ports.

45.5.1.4 Tone Control Action register

The bit definitions for the Tone Control Action register are shown in Table 45–47. This register is defined for only "-O" ports.

Table 45–47—Tone Control Action register bit definitions

Bit(s)	Name	Description	R/W
1.x.15:5	reserved	Value always 0, writes ignored	R/W[a]
1.x.4	Refresh tone table	1 = refresh the contents of the selected tones' entries in the Tone Table 0 = ready, operation complete Note: Refreshing a large number of tones may take a long time to complete.	R/W, SC
1.x.3	Change tone activity	1 = activate Tone active setting as in Tone Control Parameter reg. 0 = ready, operation complete	R/W, SC
1.x.2	Change tone direction	1 = activate Tone direction setting as in Tone Control Parameter reg. 0 = ready, operation complete	R/W, SC
1.x.1	Change SNR margin	1 = activate Min and Max SNR margin settings as in Tone Control Parameter register 0 = ready, operation complete	R/W, SC
1.x.0	Change PSD level	1 = activate PSD level setting as in Tone Control Parameter reg. 0 = ready, operation complete	R/W, SC

[a]RW = Read/Write

45.5.1.5 Tone Table

The Tone Table allows a STA to query the status of any individual tone in the link. Tone parameters are addressed directly as registers in the Tone Table MMD (address 6). Some of the values in each Tone Table entry are read from the link partner. Because the constant update of these values would be a strain on channel resources, these values are only updated on particular tones when the "Refresh tone table" command is issued in the Tone Control Action register.

Editor's Note: Alternately, the tone table might contain only local data for each tone. Since the tone table exists on both ends of the link, EFM OAM could be used to gather tone data from the remote tone table. Using OAM would be much faster and less burdensome on the PHY control channel. Please share your comments!

Each individual table entry in the table is 6 bytes. Each tone's index into the table is equal to the tone number times 3. For example, to query tone 4, the STA would query 6.12, 6.13 and 6.14. Tone 1229 would be accessed at 6.3687, 6.3688 and 6.3689. The organization of the Tone Table is shown in Figure 45–1.

Tone Table entry bit definitions are given in Table 45–48.

45.6 PMA/PMD Registers for 2BASE-TL

45.6.1 2BASE-TL Control Registers

45.6.1.1 General Parameter register

The General Parameter register controls various parameters for the operation of the 2BASE-TL PMA/PMD.

See (REFERENCE REQUiRED)

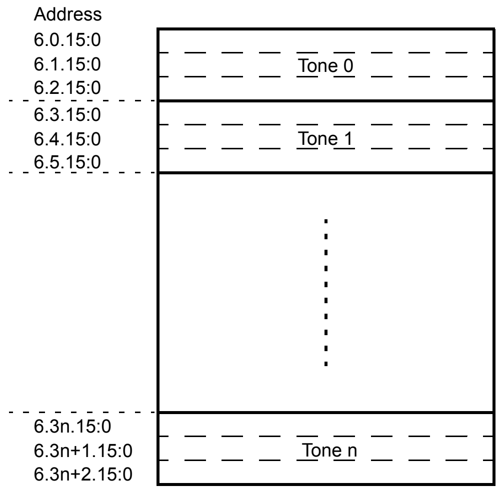

Figure 45–1—Tone Table Organization

Table 45–48—Tone Table Entry registers bit definitions

Bit(s) t := tone #	Name	Description	R/W
6.3t.15	Refresh status	0 = tone entry has not been refreshed since last read 1 = tone entry has been refreshed	RO[a], CR
6.3t.14	Active	0 = tone is active 1 = tone is disabled	RO
6.3t.13	Direction	0 = tone is assigned for DS communication 1 = tone is assigned for US communication	RO
6.3t.12:8	reserved	Value always 0, writes ignored	RO
6.3t.7:0	RX PSD	PSD of the tone at the receiver in dBm/Hz	RO
6.3t+1.15:8	TX PSD	PSD of the tone at the transmitter in dBm/Hz	RO
6.3t+1.7:3	Bit load	The number of bits currently loaded on the tone	RO
6.3t+1.2:1	reserved	Value always 0, writes ignored	RO
6.3t+1.0, 6.3t+2.15:8	SNR margin	Current SNR margin for the tones R:= value of bits SNR Margin = R/4 dB	RO
6.3t+2.7:0	reserved	Value always 0, writes ignored	RO

[a]RO = Read Only

This register is defined only for “-O” ports. The selected parameters on the “-O” are sent to the “-R” link partner on link initialization.

The bit definitions for the General Parameter register are found in Table 45–49.

Table 45–49— General Parameter register bit definition

Bit(s)	Name	Description	R/W
1.x.7:2	Profile	see annex 63A	O: R/W[a] R: undefined
1.x.1:0	Region	Selects the regional annex to operate under 00 = Annex A 01 = Annex B 10 = Annex C 00 = reserved, writes ignored	O: R/W R: undefined

[a]RW = Read/Write

45.6.1.2 Local Parameters register

Table 45–50— Local Parameters register bit definition

Bit(s)	Name	Description	R/W
1.x14:9	Power	x: multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + x * 0.5) dBm	O: R/W[a] R: RO
1.x.9:2	Data Rate	n: multiple of 64kbps Data Rate =(n * 64) kbps	O: R/W R: RO
1.x.1:0	Constellation	01 = 32-TCPAM. 00 = 16-TCPAM	O: R/W R: RO

[a]RW = Read/Write

The Local Parameters register sets the transmission parameters for the PMD. When the link is initialized or reset, these parameters shall be used by the PHY transmitter. Since writing to this register does not have an immediate effect, reading this register returns the desired parameters, which are not necessarily the current operating parameters.

The bit definitions for the Local Parameters register are found in Table 45–50

45.6.1.3 Remote Parameters register

Table 45–51— Remote Parameters register bit definition

Bit(s)	Name	Description	R/W
1.x14:9	Power	x: multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + x * 0.5) dBm	O: R/W[a], D[b] R: undefined
1.x.9:2	Data Rate	n: multiple of 64kbps Data Rate =(n * 64) kbps	O: R/W, D R: undefined
1.x.1:0	Constellation	01 = 32-TCPAM. 00 = 16-TCPAM	O: R/W, D R: undefined

[a]RW = Read/Write
[b]D = the “-R” link partner is set only when appropriate activate register bit is set

The Remote Parameters register sets the transmission parameters for the “-R” link partner’s PMD. When the link is initialized or reset, these parameters shall be used by the “-R” PHY transmitter. Since writing to this register does not have an immediate effect, reading this register returns the desired parameters, which are not necessarily the current operating parameters.

This register is defined only for “-O” ports.

The bit definitions for the Remote Parameters register are found in Table 45–51

Editor’s Note: The following registers were suggested based on the resolution of Draft 1.3 comment #798. They did not make it into this draft.

PHY counters:

1) CRC Anomaly register (See G991.2 Section 9.2.1)

2) Segment Anomaly register (See G991.2 Section 9.2.2)

3) Loss of Sync Defect register (See G991.2 Section 9.2.3)

4) Loss of segment defect register (See G991.2 Section 9.2.4)

5) SNR Margin defect (9.2.5)

6) Loss of sync word defect (9.2.6)

7) Code Violation register (9.3.1)

8) Errored seconds register (9.3.2)

9) severely errored seconds register (9.3.3)

10) LOSW seconds register (9.3.4)

11) UA seconds (9.3.5)

Other

1) SHDSL version number

2) Loop attenuation threshold (9.5.5.7.5)

3) SNR margin threshold (9.5.5.7.5)

4) Power backoff status

Changes to ANSI/IEEE Std 802.3ae, 2002, Clause 46

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3ae, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions:

None.

Abbreviations:

None.

Issues:

None

Revision History:

Draft 1.414	April 2003	First changes to this clause

46. Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII)

46.3.4 Link fault signaling

Modify the second paragraph as follows:

Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. Upon recognition of a fault condition a PHY sublayer indicates Local Fault status on the data path. When this Local Fault status reaches an RS, the RS tests the unidirectional_oam_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates a Remote Fault status on the transmit data path (possibly truncating a MAC frame being transmitted). If this variable is TRUE, the RS continues to allow the transmission of MAC data but replaces all IPG with a Remote Fault status. When Remote Fault status is received by an RS, the RS tests the unidirectional_oam_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates Idle control characters. If this variable is TRUE, the RS continues to allow the transmission of MAC data. When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data.

46.3.4.2 Variables and counters

Insert new variable in proper alphabetical location:

unidirectional_oam_enable

Controls the enabling and disabling of unidirectional OAM capability. This variable should only be set when an OAM sublayer entity exists and is enabled.

Values: FALSE; Unidirectional OAM capability is not enabled

TRUE; Unidirectional OAM capability is enabled

46.3.4.3 State Diagram

Modify lettered list as follows:

a) link_fault = OK
The RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

b) link_fault = Local Fault
If unidirectional_oam_enable=FALSE, t~~T~~he RS shall continuously generate Remote Fault Sequence ordered_sets.
If unidirectional_oam_enable=TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Remote Fault Sequence ordered_sets.

c) link_fault = Remote Fault
If unidirectional_oam_enable=FALSE, t~~T~~he RS shall continuously generate Idle control characters.
If unidirectional_oam_enable=TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

The above description of link_fault = Local Fault currently breaks the 64B/66B encoder (Clause 49) when the column containing the Terminate is followed immediately by a Remote Fault Sequence ordered_set. If the 64B/66B encoder attempts to encode these 2 columns as a single 64B word, it will not find a legal encoding and treat the word as an error. See the T0, T1, T2 and T3 rows in Figure 49-7. Suggestions for complete solutions are requested as comments against D1.4 during the open comment period.

56. Introduction to Ethernet for subscriber access networks

Editors' Notes: To be removed prior to final publication.

References:

None.

Definitions: (to be added to 1.4):

None:

Abbreviations (to be added to 1.5):

LT = Line Termination
NT = Network Termination
OAM = Operations, Administration & Maintenance
OLT = Optical Line Termination
ONU = Optical Network Unit
P2P = Point to Point
P2MP = Point to Multi-Point
CO = Central Office

Revision History:

Draft 0.9 June 2002 Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.0 August 2002 Preliminary draft for IEEE P802.3ah Task Force review, incorporating comments received at July, 2002 meeting in Vancouver, BC.
Draft 1.1 October 2002 Preliminary draft for IEEE P802.3ah Task Force review, incorporating comments received at September, 2002 meeting in New Orleans, LA.
Draft 1.2 December 2002 Draft for IEEE 802.3ah Task Force review, incorporating comments received at November, 2002 meeting in Kauai, HI.
Draft 1.3 January 2003 Draft for IEEE 802.3ah Task Force review, incorporating comments received at January, 2003 meeting in Vancouver, Canada.
Draft 1.414 April 2003 Draft for IEEE 802.3ah Task Force review, incorporating comments received at March, 2003 meeting in Dallas, Texas.

56.1 Overview

Ethernet for subscriber access networks, also referred to as “Ethernet in the First Mile”, or EFM, combines a minimal set of extensions to the IEEE 802.3 Media Access Control (MAC) and MAC Control sublayers with a family of Physical (PHY) Layers. These Physical Layers include optical fiber and voice grade copper cable Physical Medium Dependent sublayers (PMDs) for point to point connections in subscriber access networks. EFM also introduces the concept of Ethernet Passive Optical Networks (EPONs), in which a point to multi-point (P2MP) network topology is implemented with passive optical splitters, along with optical fiber PMDs that support this topology. In addition, a mechanism for network Operations, Administration and Maintenance (OAM) is included to facilitate network operation and troubleshooting. The relationships between these EFM elements and the ISO/IEC Open System Interconnection (OSI) reference model are shown in Figure 56–1 for the case of point to point topologies, and Figure 56–2 for the case of point to multi-point topologies.

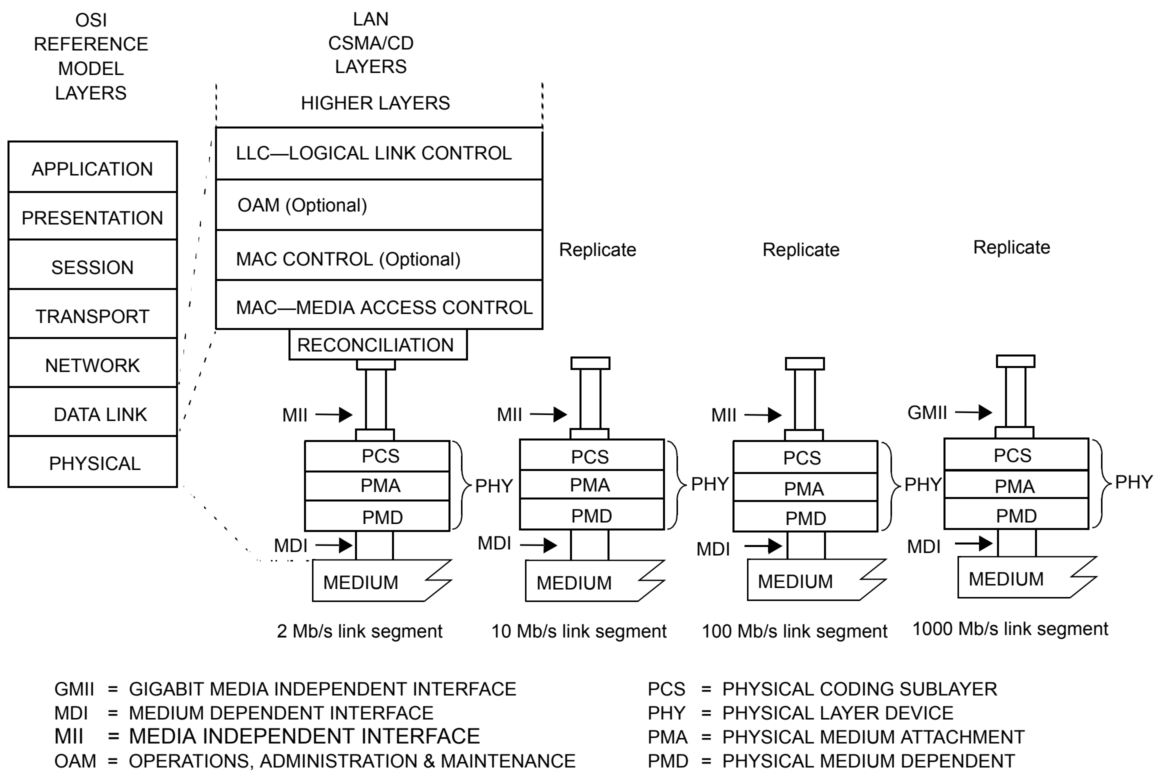

Figure 56–1—Architectural positioning of EFM: P2P Topologies

EFM supports operation at several different bit rates, depending on the characteristics of the underlying medium. In the case of point to point optical fiber media, bit rates of 100 Mb/s and 1000 Mb/s are supported, using the 100BASE-X and 1000BASE-X Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayers defined in Clause 24 and Clause 36, respectively. In the case of point to point copper, EFM supports a variety of bit rates, depending on the span and the Signal to Noise Ratio (SNR) characteristics of the medium as described in Clauses 61-63. In the case of P2MP optical fiber topologies, EFM supports a nominal bit rate of 1000 Mb/s, shared amongst the population of Optical Network Units (ONUs) attached to the P2MP topology.

An important characteristic of EFM is that only full duplex links are supported in subscriber access networks. The timing constraints of the CSMA/CD protocol make it impractical to build subscriber access networks of reasonable extent. However, for the purposes of PHY-MAC rate matching, the MAC is configured

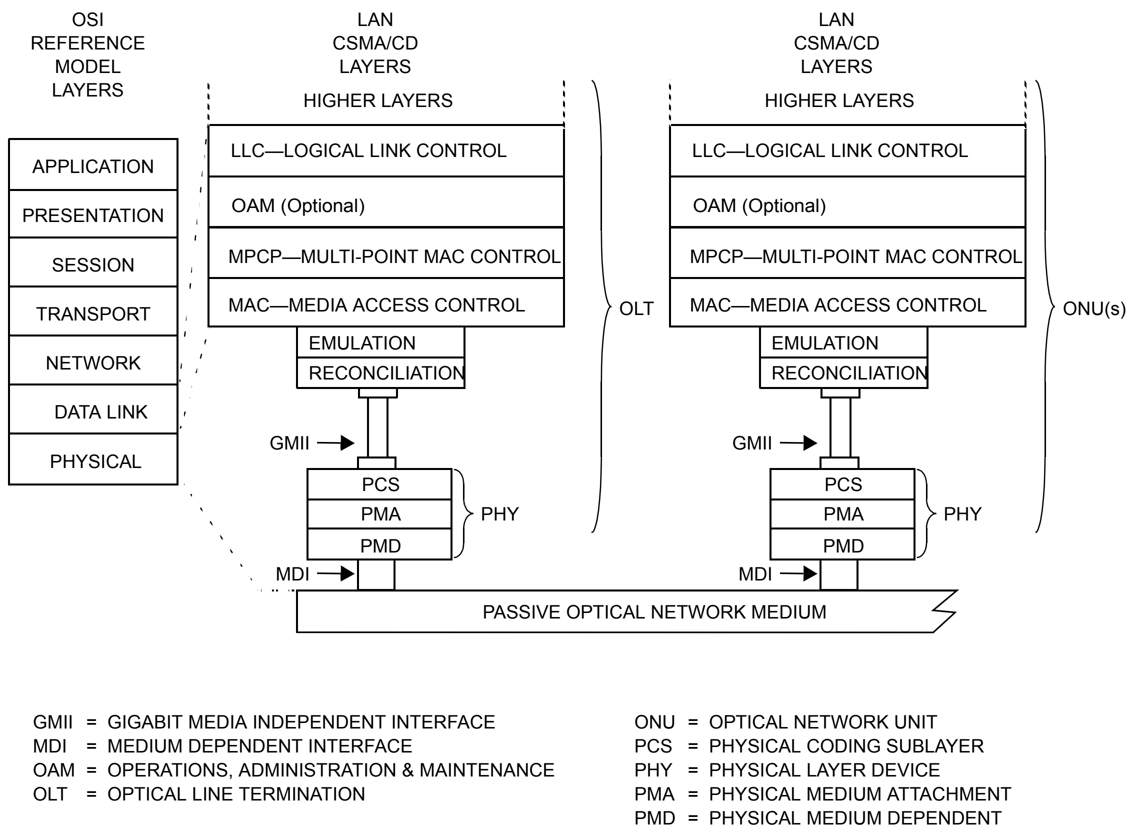

Figure 56–2—Architectural positioning of EFM: P2MP Topologies

in the half duplex operating mode when used with a Clause 61 PHY. The PHYs defined by Clauses 61-63 perform simultaneous transmission and reception of data, allowing full duplex communication at the MAC sublayer to be accomplished by the rapid exchange of frames.

56.1.1 Multi-Point MAC Control Protocol (MPCP)

The Multi-Point MAC Control Protocol (MPCP) uses messages, state machines, and timers, as defined in Clause 64, to control access to a P2MP topology. Every P2MP topology consists of one Optical Line Termination (OLT) plus one or more ONUs, as shown in Figure 56–2. Each ONU in the P2MP topology contains an instance of the MPCP, which communicates with an instance of the MPCP in the OLT.

56.1.2 Point to Point Emulation Sublayer

The P2P Emulation Sublayer makes an underlying P2MP network appear as a collection of point to point links to the higher protocol layers (at and above the MAC Client). It achieves this by prepending a Logical Link Identification (LLID) to the beginning of each packet, replacing two octets of the preamble. This sublayer is described in Clause 65.

56.1.3 Reconciliation Sublayer (RS) and Media Independent Interfaces (MII)

The MII and GMII defined in Clause 22 and Clause 35, respectively, are employed for the same purpose in EFM, that being the interconnection between the MAC sublayer and the PHY Layer entities, and between PHY Layer and Station Management (STA) entities. Extensions to the RS and GMII for P2MP topologies are described in Clause 65.

56.1.4 Physical Layer signaling systems

EFM extends the family of 100BASE-X Physical Layer signaling systems to include 100BASE-LX10 (extended Long wavelength laser), plus the combination of the 100BASE-BX10-D (Bidirectional long wavelength Downstream laser) and the 100BASE-BX10-U (Bidirectional long wavelength Upstream laser), as defined in Clause 60. All of these systems employ the 100BASE-X PCS and PMA as defined in Clause 24.

EFM also extends the family of 1000BASE-X Physical Layer signaling systems to include 1000BASE-LX10 (extended Long wavelength laser), plus the combination of the 1000BASE-BX10-D (Bidirectional long wavelength Downstream laser) and the 1000BASE-BX10-U (Bidirectional long wavelength Upstream laser), as defined in Clause 59. All of these systems employ the 1000BASE-X PCS and PMA as defined in Clause 36.

For P2MP topologies, EFM introduces a family of Physical Layer signaling systems which are derived from 1000BASE-X, but which include enhancements to the RS, GMII, PCS and PMA, along with an optional Forward Error Correction (FEC) capability, as defined in Clause 65. The family of P2MP Physical Layer signaling systems includes the combination of the 1000BASE-PX10-D (Passive Optical Network Downstream laser 10 km), plus the 1000BASE-PX10-U (PON Upstream laser 10 km), and the combination of the 1000BASE-PX20-D (PON Downstream laser 20 km) plus the 1000BASE-PX20-U (PON Upstream laser 20 km), as defined in Clause 58.

Editor's note: The following paragraphs will be rewritten once a final determination has been made regarding the modulation technique for the short reach copper PHY. For now, the text introduces both of the short reach copper PHY proposals. At most, only one modulation technique will be defined within 802.3ah for the short reach copper PHY. Further, appropriate text was modified to reflect the copper PHY subtypes.

For copper cabling, EFM introduces a family of Physical Layer signaling systems. At the time this document was written, there were four distinct signaling systems proposed for copper cabling. All of them share a set of common functions and interfaces as described in Clause 61. Clause 61 also includes an optional specification that supports combined operation on multiple copper pairs, affording greater data rate capability for a given link span. Underlying these functions, a set of PMD specific functions are described in Clauses 62 and 63.

For high speed applications, the 10PASS-TS signaling system is defined in Clause 62. 10PASS-TS relies on a technique referred to as Frequency Division Duplexing (FDD) to accomplish full duplex communication on a single wire pair. At the time this document was written, two distinct PMDs were being considered for 10PASS-TS. A PMD based on Single Carrier Modulation (SCM, also referred to as Quadrature Amplitude Modulation or QAM) is described in Clause 62, as is a PMD based on Multiple Carrier Modulation (MCM, also referred to as Discrete Multi-Tone or DMT). Both of these PMDs use passband signaling, and support a nominal full duplex data rate of 10 Mb/s, hence the identifier 10PASS-TS. For the 10PASS-TS PHY, two subtypes are defined: 10PASS-TS-O and 10PASS-TS-R. A connection can only be established between a 10PASS-TS-O PHY on one end of the voice-grade copper line, and a 10PASS-TS-R PHY on the other end. In public networks, a 10PASS-TS-O PHY is used at a central office (CO), a cabinet or other centralized distribution point; a 10PASS-TS-R PHY is used at the subscriber premises. In private networks, the network administrator will designate one end of each link as the CO side. A PHY implementation may be equipped to support both subtypes and provide means to be configured as a 10PASS-TS-O or a 10PASS-TS-R.

For long distance applications, EFM introduces a new distinct PMD, 2BASE-TL. The 2BASE-TL signaling system is defined in Clause 63. 2BASE-TL is a baseband signaling system derived from the Single-Pair High-Speed Digital Subscriber Line (SHDSL) standards defined by T1E1 and ITU-T. This PMDs support a nominal full duplex data rate of approximately 2 Mb/s. As is the case with the 10PASS-TS PHY, the 2BASE-TL PHY consists of two subtypes: 2BASE-TL-O (CO side) and 2BASE-TL-R (subscriber side).

Specifications unique to the operation of each physical layer device are shown in Table 56–1.

Table 56–1—Summary of EFM Physical Layer Signaling Systems

Name	Location	Rate (Mb/s)	Nominal Span (km)	Medium	Clause
100BASE-LX10	ONU/OLT	100	10	Duplex single-mode fibers	60
100BASE-BX10-D	OLT	100	10	Simplex single-mode fiber	60
100BASE-BX10-U	ONU	100	10	Simplex single-mode fiber	60
1000BASE-LX10	ONU/OLT	1000	10 0.55	Duplex single-mode fibers Duplex multimode fibers	59
1000BASE-BX10-D	OLT	1000	10	Simplex single-mode fiber	59
1000BASE-BX10-U	ONU	1000	10	Simplex single-mode fiber	59
1000BASE-PX10-D	OLT	1000	10	Simplex single-mode fiber PON	58
1000BASE-PX10-U	ONU	1000	10	Simplex single-mode fiber PON	58
1000BASE-PX20-D	OLT	1000	20	Simplex single-mode fiber PON	58
1000BASE-PX20-U	ONU	1000	20	Simplex single-mode fiber PON	58
10PASS-TS-O	CO[a]	varies	varies	One or more pairs of voice grade copper cable	62
10PASS-TS-R	Subscriber[a]	varies	varies	One or more pairs of voice grade copper cable	62
2BASE-TL-O	CO[a]	varies	varies	One or more pairs of voice grade copper cable	63
2BASE-TL-R	Subscriber[a]	varies	varies	One or more pairs of voice grade copper cable	63

[a]In private networks, the network administrator will designate one end of each link as the CO side.

56.1.5 Management

Managed objects, attributes, and actions are defined for all EFM components (Clause 30). That clause consolidates all IEEE 802.3 management specifications so that agents can be managed by existing network management stations with little or no modification to the agent code, regardless of the operating speed of the network.

In addition to the management objects, attributes, and actions defined in Clause 30, EFM introduces Operations, Administration, and Maintenance (OAM) for subscriber access networks to Ethernet. OAM, as defined in Clause 57, includes a mechanism for communicating management information using OAM frames, as well as functions for performing low level diagnostics on a per link basis in an Ethernet subscriber access network.

56.2 State diagrams

State machine diagrams take precedence over text.

The conventions of 1.2 are adopted, along with the extensions listed in 21.5.

56.3 Protocol Implementation Conformance Statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE 802.3, Clauses 57 through 65, shall complete a Protocol Implementation Conformance Statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the EFM PICS conforms to the same notation and conventions used in 100BASE-T (see 21.6).

56.4 Relation of EFM to other standards

The relation of 2BASE-TL and 10PASS-TS to other standards can be found in 61.1.3.

57. Operations, Administration and Maintenance (OAM)

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

None.

Definitions (to be added to 1.4):

administration: A group of network support functions that sustain link operation.

maintenance: An activity concerned with, but not limited to, failure detection, notification, location, and repairs, that is intended to eliminate faults and keep a link in an operational state.

operations: Support activities required to provide the services of a subscriber access network to users/subscribers.

Abbreviations (to be added to 1.5):

OAM: Operations, Administration and Maintenance

Revision History:

Draft 0.9	June 2002	Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.0	August 2002	Initial draft for IEEE P802.3ah Task Force review.
Draft 1.1	October 2002	Revised draft as a result of IEEE P802.3ah Task Force review in New Orleans.
Draft 1.2	December 2002	Revised draft as a result of IEEE P802.3ah Task Force review in Kauai.
Draft 1.3	January 2003	Revised draft as a result of IEEE P802.3ah Task Force review in Vancouver.
Draft 1.414	April 2003	Revised draft as a result of IEEE P802.3ah Task Force review in Dallas.

57.1 Overview

57.1.1 Scope

This clause defines the Operations, Administration and Maintenance (OAM) sublayer which provides mechanisms useful for monitoring link operation such as remote fault indication and remote loopback control. OAM provides network operators the ability to monitor the health of the network and quickly determine the location of failing links or fault conditions. OAM provides data link layer mechanisms that complement applications that may reside in higher layers.

OAM information is conveyed in IEEE 802.3 frames called OAM Protocol Data Units. OAMPDUs contain the appropriate control and status information used to monitor, test and troubleshoot IEEE 802.3 links. OAMPDUs traverse a single link and are not forwarded by bridges or switches. OAMPDUs are transferred between OAM peer entities.

OAM does not include functions such as station management, bandwidth allocation or provisioning functions, which are considered outside the scope of IEEE 802.3.

57.1.2 Summary of objectives and major concepts

This section provides details and functional requirements for the OAM objectives:

a) Remote Failure Indication
   1) A mechanism is provided to indicate to a peer that the receive path of the local device is non-operational.
   2) Subscriber access physical layer devices, defined in Clauses 59, 60, 62 and 63 support unidirectional operation to allow OAM remote fault indication during fault conditions (See Table 57–7).
   3) Subscriber access physical layer devices, defined in Clause 58, support unidirectional operation in the direction from OLT to ONU that allows OAM remote fault indication from OLT during fault conditions.
   4) Physical layer devices other than those defined in Clauses 58, 59, 60, 62 and 63 may support unidirectional operation thus allowing OAM remote fault indication during fault conditions.
b) Remote Loopback
   1) A mechanism is provided to support a data link layer frame-level loopback mode.
c) Link Monitoring
   1) A mechanism is provided to support event notification that permits the inclusion of diagnostic information.
   2) A mechanism is provided to support polling of any variable in the IEEE 802.3 MIB.
d) Miscellaneous
   1) Activation of OAM is optional.
   2) A mechanism is provided that performs OAM capability discovery.
   3) A vendor extension mechanism is provided and made available for higher layer management applications.

57.1.3 Summary of non-objectives

This section explicitly lists certain functions that are not addressed by OAM. These functions, while valuable in subscriber access networks, do not fall within the scope of IEEE 802.3.

a) Management functions not pertaining to a single link such as protection switching, station management and subscriber management are not covered by this clause. Such functions could be addressed using the vendor extension mechanism.
b) Provisioning and negotiation functions such as bandwidth allocation, rate adaptation and speed/duplex negotiation are not supported by OAM.

c) Issues related to privacy of OAM data and authentication of OAM entities are beyond the scope of this clause.

d) The ability to set/write remote MIB variables is not supported.

57.1.4 Positioning of OAM within the IEEE 802.3 architecture

OAM comprises an optional sublayer between a superior sublayer (e.g. MAC Client or optional Link Aggregation) and a subordinate sublayer (e.g. MAC or optional MAC Control sublayer). Figure 57–1 depicts the positioning of the OAM sublayer in the IEEE 802.3 layer architecture, and the relationship of that architecture to the Data Link and Physical Layers of the OSI Reference Model.

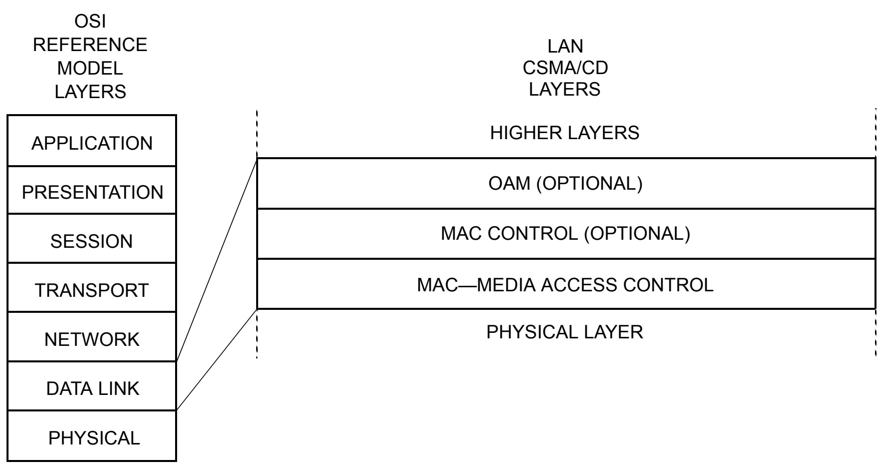

Figure 57–1—Architectural positioning of OAM sublayer

57.1.5 Compatibility Considerations

57.1.5.1 Application

OAM is intended for point-to-point and emulated point-to-point IEEE 802.3 links. Implementation of OAM functionality is optional. A conformant implementation may implement the optional OAM sublayer for some ports within a system while not implementing it for other ports.

57.1.5.2 Interoperability between OAM capable devices

A device is able to determine whether or not a remote device has OAM functionality enabled. The OAM Discovery mechanism ascertains the configured parameters, such as maximum allowable OAMPDU size, and supported functions, such as remote loopback, on a given link.

57.1.5.3 MAC Control PAUSE

MAC Control PAUSE, commonly referred to as Flow Control as defined in *CROSS REF* Annex 31B, inhibits the transmission of all MA_DATA.request primitives, including OAMPDUs. This may delay or prevent the signaling of critical events such as unrecoverable failure conditions and link faults.

57.1.5.4 OAM loopback

Invocations of OAM loopback may result in data frame loss. OAM loopback is an intrusive operation that prevents a link from passing frames between the MAC Client of the local device and the MAC Client of the remote device. Refer to 57.2.8 for a complete description of loopback operation.

57.1.6 State diagram conventions

Many of the functions specified in this clause are presented in state diagram notation. All state diagrams contained in this clause use the notation and conventions defined in *CROSS REF* 21.5. In the event of a discrepancy between the text description and the state diagram formalization of a function, the state diagrams take precedence.

57.2 Functional specifications

57.2.1 Block diagram

Figure 57–2 depicts the major blocks within the OAM sublayer and their interrelationships.

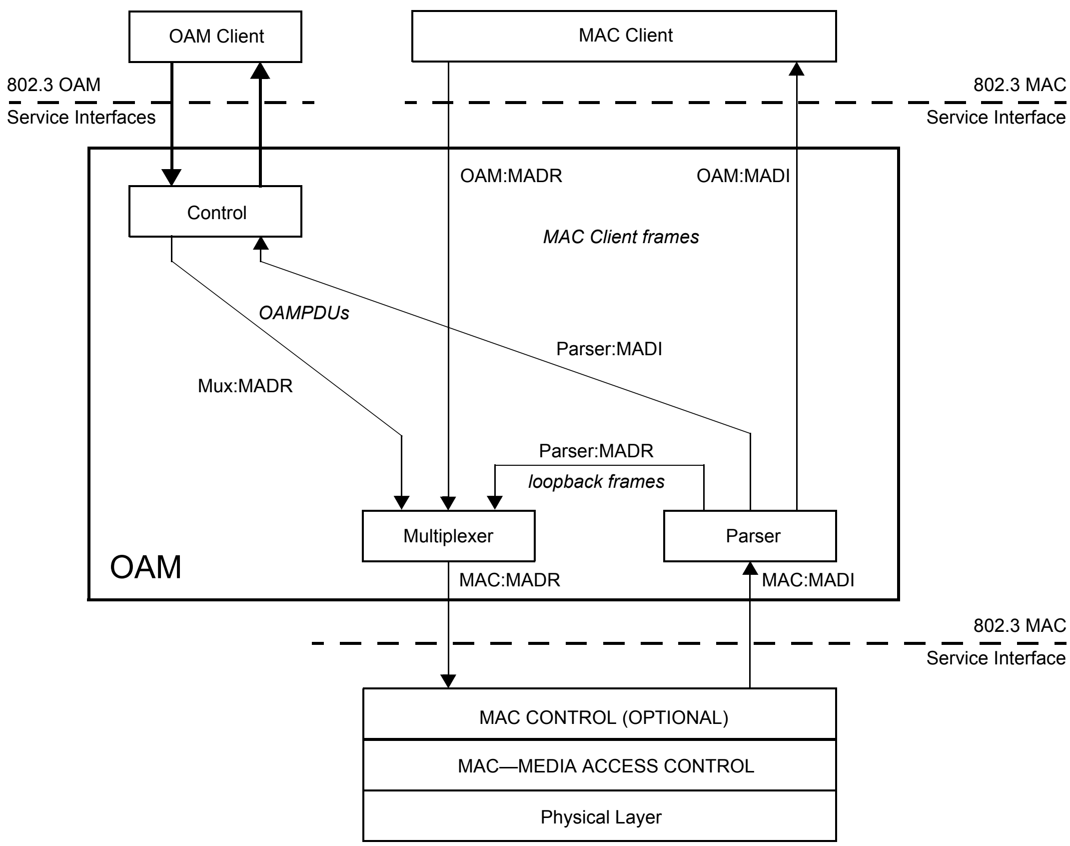

Figure 57–2—OAM sublayer block diagram

57.2.2 Principles of operation

OAM employs the following principles and concepts:

a) The OAM sublayer presents a standard IEEE 802.3 service interface to the superior sublayer. Superior sublayers include MAC Client and Link Aggregation.

b) The OAM sublayer employs a standard IEEE 802.3 service interface to the subordinate sublayer. Subordinate sublayers include MAC and MAC Control.
c) Frames from superior sublayers are multiplexed within the OAM sublayer with OAMPDUs.
d) The OAM sublayer parses received frames and passes OAMPDUs to the OAM client. When not in OAM loopback mode, non-OAMPDUs are passed to the superior sublayer. When in OAM loopback mode, non-OAMPDUs are looped back to the subordinate sublayer.
e) Knowledge of the underlying physical layer device is not required by the OAM sublayer.
f) OAMPDUs traverse a single link and are passed between OAM client entities or OAM sublayer entities. OAMPDUs are not forwarded by IEEE 802.1 bridges.
g) OAM is extensible through the use of an organizationally specific OAMPDU and vendor specific event TLVs. These can be used for functions outside the scope of IEEE 802.3.

57.2.3 Responsibilities of OAM client

The OAM client plays an integral role in establishing and managing OAM on a link. After receiving an Information OAMPDU from the remote device, the OAM client sets the OAM_CTL.request parameter remote_state_valid. This allows Active devices (See 57.2.6.1) to proceed through the OAM Discovery process (See 57.3.2.1) and allows Passive devices (See 57.2.6.2) to begin sending Information OAMPDUs. After comparing local and remote state and configuration information, the OAM client sets the OAM_CTL.request parameter local_satisfied if it is satisfied with the settings on the link. This allows OAM to be established on the link.

After OAM has been established on a link, the OAM client is responsible for adhering to the OAMPDU response rules found in 57.4. The OAM client does not respond to illegal requests such as Variable Request and Loopback Control OAMPDUs from Passive devices.

Events, discussed at length in 57.2.7, are signalled between peer OAM client entities. The OAM client handles this by sending Event Notification OAMPDUs (See). To increase the likelihood that a particular event is received by the remote device, the OAM client may send the event multiple times. The Event Notification OAMPDU contains a sequence number. The sequence number is incremented whenever a new event is to be sent. The OAM client ignores Event Notification OAMPDUs with duplicate sequence numbers.

57.2.4 Instances of the MAC service interface

A superior sublayer such as the MAC Client communicates with the OAM sublayer using the standard MAC service interface specified in *CROSS REF* Clause 2. Similarly, the OAM sublayer communicates internally and with a subordinate sublayer such as the MAC Control or MAC using the same standard service interfaces.

MAC Control Clients that generate MA_CONTROL.request primitives (and which expect MA_CONTROL.indication primitives in response) are not acted upon by the OAM sublayer. They communicate directly with the MAC Control entity as though no OAM sublayer exists.

Since OAM uses four instances of the MAC service interface, it is necessary to introduce a notation convention so that the reader can be clear as to which interface is being referred to at any given time. A prefix is therefore assigned to each service primitive, indicating which of the four interfaces is being invoked, as depicted in Figure 57–2. The prefixes are as follows:

a) OAM:, for primitives issued on the interface between the superior sublayer and the OAM sublayer.
b) Parser:, for primitives issued on the interface between the Parser and other OAM functions.
c) Mux:, for primitives issues on the interface between the Multiplexer and other OAM functions.
d) MAC:, for primitives issued on the interface between the underlying subordinate sublayer (e.g. MAC) and the OAM sublayer.

57.2.5 OAM client interactions

The OAM sublayer entity communicates with the OAM client using the following new interlayer service interfaces:

OAMPDU.request
OAMPDU.indication
OAM_CTL.request
OAM_CTL.indication

57.2.5.1 Basic services and options

The OAMPDU.request, OAMPDU.indication, OAM_CTL.request and OAM_CTL.indication service primitives described in this subclause are mandatory.

57.2.5.2 OAMPDU.request

57.2.5.2.1 Function

This primitive defines the transfer of data from an OAM client entity to a peer OAM client entity.

57.2.5.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMPDU.request          (
                        source_address,
                        flags,
                        code,
                        data
                        )
```

The source_address parameter specifies an individual MAC address. The flags parameter is used to create the Flags field within the OAMPDU to be transmitted. The code parameter is used to create the Code field within the OAMPDU to be transmitted. The data parameter is used to create the Data field within the OAMPDU to be transmitted.

57.2.5.2.3 When generated

This primitive is generated by the OAM client entity whenever an OAMPDU shall be transferred to a peer entity. This can be in response to a request from the peer entity or from data generated internally to the OAM client.

57.2.5.2.4 Effect of receipt

The receipt of this primitive will cause the OAM sublayer entity to insert all OAMPDU specific fields, including DA, SA, Length/Type and Subtype, and pass the properly formed OAMPDU to the lower protocol layers for transfer to the peer OAM client entity.

57.2.5.3 OAMPDU.indication

57.2.5.3.1 Function

This primitive defines the transfer of data from an OAM sublayer entity to an OAM client entity.

57.2.5.3.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMPDU.indication        (
                         source_address,
                         flags,
                         code,
                         data
                         )
```

The source_address parameter is the MAC source address of the incoming OAMPDU. The flags parameter is the Flags field of the incoming OAMPDU. The code parameter is the Code field of the incoming OAMPDU. The data parameter is the Data field of the incoming OAMPDU.

57.2.5.3.3 When generated

The OAMPDU.indication is passed from the OAM sublayer entity to the OAM client entity to indicate the arrival of an OAMPDU to the local OAM sublayer entity that is destined for the OAM client. Such OAMPDUs are reported only if they are validly formed and received without error.

57.2.5.3.4 Effect of receipt

The effect of receipt of this primitive by the OAM client is unspecified.

57.2.5.4 OAM_CTL.request

57.2.5.4.1 Function

This primitive defines the transfer of control information from an OAM client entity to an OAM sublayer entity.

57.2.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAM_CTL.request          (
                         local_oam_enable,
                         local_oam_mode,
                         local_link_status,
                         local_unidirectional,
                         local_satisfied,
                         local_dying_gasp,
                         local_critical_event,
                         local_mux_action,
                         local_par_action,
                         local_time_stamp,
                         remote_stable,
                         remote_state_valid,
                         information_data
                         )
```

The local_oam_enable parameter is used to enable and disable the OAM sublayer entity. Disabling and re-enabling the local_oam_enable parameter shall cause a reset of the OAM sublayer entity. When this parameter is disabled, the interface will act as it would if it had no OAM sublayer. The local_oam_mode parameter is used to configure the OAM sublayer entity in either Active or Passive mode. The local_link_status parameter is used to convey the status of the link as determined by the underlying physical layer. The local_unidirectional parameter is used to enable unidirectional transmission of OAMPDUs, supported by some physical coding sublayers. The local_satisfied parameter is set by the OAM client as a result of comparing its local configuration and the remote configuration found in the received remote OAM_Information TLV. The local_dying_gasp parameter is used to signal a local unrecoverable failure condition. When set, the local_dying_gasp parameter will cause the OAM sublayer entity to transmit an Information OAMPDU with the Dying Gasp bit of the Flags field set. The local_critical_event parameter is used to signal a critical link event condition. When set, the local_critical_event parameter will cause the OAM sublayer entity to transmit an Information OAMPDU with the Critical Event bit of the Flags field set. The local_mux_action parameter is used to govern the flow of non-OAMPDUs by the Multiplexer function. The local_par_action parameter is used to govern the flow of non-OAMPDUs by the Parser function. The local_time_stamp parameter provides a time reference and is included in Event TLVs (See 57.5.3). The remote_stable parameter is used in Information OAMPDUs for Discovery or to keep the OAM Discovery process from re-starting. The remote_state_valid parameter is used for Discovery. The information_data parameter contains the Local Information TLV fields and, if available, the Remote Information TLV fields to be included in Information OAMPDUs sent automatically each second by the OAMPDU Transmit state diagram (See Figure 57–5).

57.2.5.4.3 When generated

The OAM_CTL.request is passed from the OAM client entity to the OAM sublayer to update control information.

57.2.5.4.4 Effect of receipt

The receipt of this primitive will cause the OAM sublayer to generate Information OAMPDUs or update specific fields of future Information OAMPDUs. Also, OAM functions will be re-evaluated based upon any changing control information.

57.2.5.5 OAM_CTL.indication

57.2.5.5.1 Function

This primitive defines the transfer of control information from an OAM sublayer entity to an OAM client entity.

57.2.5.5.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAM_CTL.indication          (
                            local_stable,
                            local_lost_link_timer_done,
                            remote_flags_field,
                            )
```

The local_stable parameter is used to pass state information from the Discovery process. The local_lost_link_timer_done parameter is used to convey the expiration of the lost_link_timer. The remote_flags_field parameter is used to convey the Flags field of the incoming OAMPDU.

57.2.5.5.3 When generated

The OAM_CTL.indication is passed from the OAM sublayer entity to the OAM client entity to indicate the change of local state information. Also, the OAM_CTL.indication is passed to indicate the value of the Flags field upon the arrival of a validly formed, error-free OAMPDU.

57.2.5.5.4 Effect of receipt

The effect of receipt of this primitive by the OAM client is unspecified.

57.2.6 Modes

Devices may be configured to be in either active or passive mode. Table 57–1 contains the capabilities of active and passive mode devices.

Table 57–1—Active and passive mode capabilities

Capability	Active device	Passive device
Initiates OAM Discovery process	Yes	No
Reacts to OAM Discovery process initiation	Yes	Yes
Required to send Information OAMPDUs	Yes	Yes
Permitted to send Event Notification OAMPDUs	Yes[a]	Yes
Permitted to send Variable Request OAMPDUs	Yes	No
Permitted to send Variable Response OAMPDUs	Yes[a]	Yes
Permitted to send Loopback Control OAMPDUs	Yes	No
Reacts to Loopback Control OAMPDUs	Yes[a]	Yes
Permitted to send Vendor Specific OAMPDUs	Yes	Yes

[a]Conditional on the peer device being an Active device

57.2.6.1 Active mode

Active devices initiate the exchange of Information OAMPDUs as defined by the Discovery state diagram (See Figure 57–4). Once the Discovery process completes, active OAM devices are permitted to send any OAMPDU.

57.2.6.2 Passive mode

Passive OAM devices do not initiate the Discovery process (See Figure 57–4). Passive devices react to the initiation of the Discovery process by the remote device. This eliminates the possibility of passive to passive links. Passive OAM devices shall not send Variable Request or Loopback Control OAMPDUs.

57.2.7 OAM events

OAM defines a set of events that may impact link operation. OAM contains mechanisms to communicate such events to the remote device. The following sections provide an overview of these events and mechanisms. The complete list of the defined Event TLVs is found in 57.5.3.

57.2.7.1 Critical link events

Table 57–2 lists the defined critical link events. Critical link events are carried within the Flags field of each OAMPDU. Refer to 57.4.2.1 for the definition of the Flags field.

Table 57–2—Critical link events

Critical link event	Description
Link fault	The PHY has determined a fault has occurred in the receive direction (e.g. link, Physical layer) of the local device.
Dying gasp	An unrecoverable local failure condition has occurred.
Critical event	An undefined critical event has occured.

57.2.7.2 Link events

Link events are signaled via Event TLVs that are defined in 57.5.3. Examples of link events include Errored Symbol Period Event and Errored Frame Seconds Event.

57.2.7.3 Local event procedure

Local events are communicated to the remote device via one of two mechanisms described below:

a) Critical link events defined in 57.2.7.1 shall be communicated to the OAM sublayer via the OAM_CTL.request service primitive, which results in the appropriate bits within the Flags field being set on all ensuing OAMPDUs.
b) The OAM client sends an Event Notification OAMPDU (See) containing an Event TLV (See Table 57–10) for every event not yet signaled to the remote device. The OAM client uses the OAMPDU.request service primitive to send Event Notification OAMPDUs. Optionally, the OAM client may send duplicate Event Notification OAMPDUs to increase the likelihood of reception at the remote device on deteriorating links.

57.2.7.4 Remote event procedure

Remote events are detected by the local OAM client via one of two mechanisms described below:

a) Critical link events defined in 57.2.7.1 shall be detected by the local OAM sublayer via the Flags field of any received OAMPDU. The OAM sublayer signals the Flags field has changed to the OAM client using the OAM_CTL.indication primitive.
b) All other link events shall be detected by the local OAM sublayer via the reception of an Event Notification OAMPDU and the subsequent passing of the OAMPDU to the OAM client via the OAMPDU.indication primitive. The OAM client discards any duplicate received Event Notification OAMPDUs.

57.2.8 OAM remote loopback

OAM provides a data link layer frame-level loopback mode, which is controlled remotely. Remote loopback is used for fault localization and link performance testing. Statistics from both the local and remote device can be queried and compared at any time while the remote device is in OAM loopback mode. These queries can take place before, during or after loopback frames have been sent to the remote device. In addition, an implementation may analyze loopback frames to determine additional information about the health of the link (i.e. determine which frames are being dropped due to link errors). Figure 57–3 shows the path of frames traversing the layer stack of both the local and remote devices.

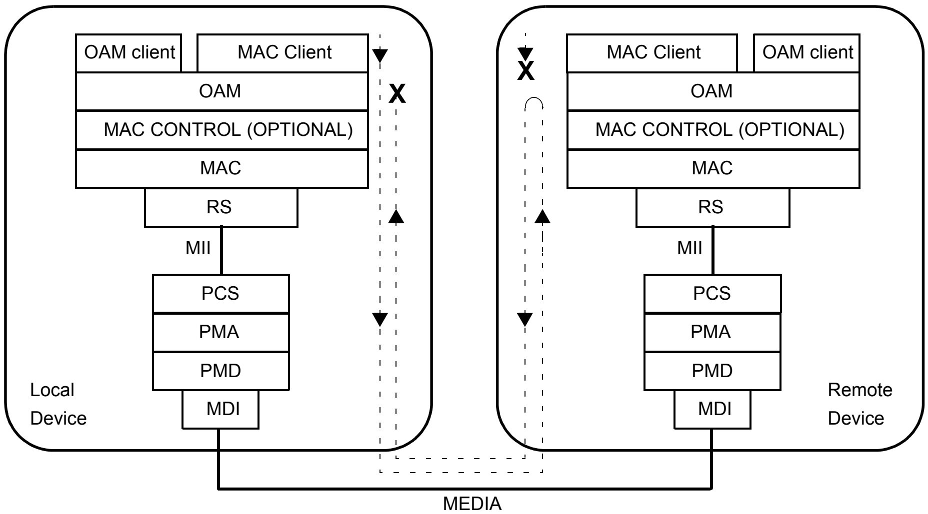

Figure 57–3—OAM loopback

57.2.8.1 Initiating OAM loopback

To initiate remote loopback, the local MAC Client stops sending data frames to the remote device and the local OAM client sets its local_par_action parameter to DISCARD via the OAM_CTL.request service primitive. The local OAM client sends a Loopback Control OAMPDU (See 57.4.3.5) with the Enable Remote Loopback command. After receiving the Loopback Control OAMPDU, the remote OAM client first sets its local_par_action parameter to LB via the OAM_CTL.request primitive, and then sends an Information OAMPDU (See 57.4.3.1) with updated state information reflecting the its local_par_action set to LB.

In the event two Active devices simultaneously send Loopback Control OAMPDUs with Enable Remote Loopback commands, the device with the lower source_address ignores the received Loopback Control OAMPDU. The device with the higher source_address acts upon the received Loopback Control OAMPDU and enters remote loopback mode.

57.2.8.2 During OAM loopback

This section elaborates on Figure 57–3 and describes the flow of frames within the local and remote devices and across the link during loopback mode. While in loopback mode:

a) The local device transmits frames from the MAC Client and OAMPDUs from the local OAM client or OAM sublayer.
b) Within the remote OAM sublayer entity, every non-OAMPDU, including other Slow Protocol frames, is looped back.
c) OAMPDUs received by the remote device are passed to the remote OAM client.
d) The remote device is required to send OAMPDUs to the local device in order to keep the Discovery process from re-starting. It is also permitted to send other OAMPDUs to the local device.
e) Frames received by the local device are parsed by the OAM sublayer. OAMPDUs are passed to the OAM client and all other frames are discarded.

57.2.8.3 Exiting OAM loopback

When the local device wishes to end the OAM loopback test, the local MAC client stops sending frames. The local OAM client then sends a Loopback Control OAMPDU with the Disable Remote Loopback command. After receiving a Loopback Control OAMPDU with the Disable Remote Loopback command, the remote OAM client first sends an Information OAMPDU with updated state information reflecting the local_par_action parameter set to FWD and then sets the local_par_action parameter to FWD via the OAM_CTL.request primitive. After receiving an Information OAMPDU with local_par_action set to FWD, the local OAM client sets its local_par_action parameter to FWD via the OAM_CTL.request primitive. The Parser resumes passing received non-OAMPDUs up to the MAC Client and the MAC Client resumes sending frames to the OAM sublayer.

57.2.8.4 Loss of OAMPDUs during OAM loopback

There is the possibility of OAMPDU loss before, during and after OAM loopback tests. Of particular interest to the operation of OAM loopback is the loss of Loopback Control OAMPDUs and Information OAMPDUs. The local OAM client is able to determine whether or not the remote OAM client received Loopback Control OAMPDUs by examining all received Information OAMPDUs. Since Information OAMPDUs are continually sent to keep the OAM Discovery process from re-starting, the occasional loss of an Information OAMPDU should not adversely impact the operation of OAM loopback mode.

57.2.8.5 Loss of frames during OAM loopback

While the link is operating in loopback mode, MAC Client frames originating from the remote device are not transmitted by the subordinate OAM sublayer. Depending upon the remote device's implementation of loopback, not every frame received is guaranteed to be looped back to the local device. Clock differences between the local and remote devices may also be a source of lost frames, as the delta in the rate of frames transmitted and received may overrun buffers within either device. As always, frames that incur errors during transit will be dropped by the MAC sublayer receiving the frame. Also, OAMPDUs inserted by the remote device impacts the bandwidth available to loopback frames. Implementations should take into account the topology (e.g. point-to-multipoint, asymmetrical links) when determining the rate at which to send frames during loopback. When a bidirectional link has asymmetric data rates, frame loss may occur because the transmit bandwidth is less than the received bandwidth.

Loopback frames that are discarded by the OAM sublayer within the remote device are counted. This helps determine the health of the link by distinguishing between frames discarded due to link errors and those discarded within the OAM sublayer.

57.2.8.6 Timing considerations for OAM loopback

For effective OAM loopback operation, it is necessary to place an upper bound on the response time of the remote OAM client after receiving Loopback Control OAMPDUs.

Within one second of receiving a Loopback Control OAMPDU with the Enable Remote Loopback command, the remote OAM client shall:

a) Set its local_par_action parameter to LB via the OAM_CTL.request primitive.
b) Send an Information OAMPDU with updated state information reflecting its local_par_action set to LB.

Within one second of receiving a Loopback Control OAMPDU with the Disable Remote Loopback command, the remote OAM Client shall:

c) Send an Information OAMPDU with updated state information reflecting its local_par_action set to FWD.
d) Set its local_par_action parameter to FWD via the OAM_CTL.request primitive.

57.3 Detailed functions and state diagrams

As depicted in Figure 57–2, the OAM sublayer comprises the following functions:

a) ***Multiplexer***. This block is responsible for passing frames received from the superior sublayer (e.g. MAC Client or Link Aggregation sublayer), OAMPDUs from the Control function and loopback frames from the Parser, to the subordinate sublayer (e.g. MAC Control or MAC sublayers).
b) ***Parser***. This block distinguishes among OAMPDUs, MAC Client PDUs and loopback frames and passes each to the appropriate entity (Control, superior sublayer and Multiplexer, respectively).
c) ***Control***. This block is responsible for interfacing with the OAM client entity. Also, it incorporates the Discovery mechanism which detects the existence and capabilities of OAM at the remote device.

57.3.1 State diagram variables

57.3.1.1 Constants

OAM_subtype
  The value of the Subtype field for OAMPDUs. (See *CROSS REF* Table 43B-3.)

Slow_Protocols_Multicast
  The value of the Slow Protocols Multicast Address. (See *CROSS REF* Table 43B-1.)

Slow_Protocols_Type
  The value of the Slow Protocols Length/Type field. (See *CROSS REF* Table 43B-2.)

57.3.1.2 Variables

BEGIN
  A variable that resets the functions within OAM.
  Values: TRUE; when the OAM sublayer is initialized or reinitialized, or when local_oam_enable is set to DISABLE.
  FALSE; When (re-)initialization has completed and local_oam_enable parameter is set to ENABLE.

ind_DA
ind_SA
ind_mac_service_data_unit
ind_reception_status
  The parameters of the MA_DATA.indication primitive, as defined in *CROSS REF* Clause 2.

ind_flags_field
  A parameter of the OAM_CTL.indication primitive. The value of the two octets following the Subtype field in a Slow Protocol frame. (See 57.4.2)
  Value: Integer

ind_subtype
  The value of the octet following the Length/Type field in a Slow Protocol frame. (See CROSS REF Annex 43B.)
  Value: Integer

local_critical_event
  A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This indicates the device has experienced an undefined critical event condition.
  Values: FALSE; A critical event condition has not occurred.
  TRUE; A critical event condition has occurred.

local_dying_gasp
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This indicates the device has experienced an unrecoverable failure condition.
Values: FALSE; An unrecoverable local failure condition has not occurred.
TRUE; An unrecoverable local failure condition has occurred.

local_link_status
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. Indicates the status of the established link, as determined by the PHY.
Values: FAIL; A link fault condition does exist.
OK; A link fault condition does not exist.

local_lost_link_timer_done
A parameter of the OAM_CTL.indication primitive, as defined in 57.2.5.5. This is used to indicate the local_lost_link_timer has expired.
Values: TRUE; local_lost_link_timer has expired.
FALSE; local_lost_link_timer has not expired.

local_mux_action
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This governs the flow of non-OAMPDUs within the Multiplexer (See 57.3.4) function.
Values: FWD; Multiplexer passes transmitted non-OAMPDUs to subordinate sublayer.
DISCARD; Multiplexer discards transmitted non-OAMPDUs.

local_oam_enable
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. Used to enable and disable the OAM sublayer entity.
Values: DISABLE; The interface acts as it would if it had no OAM sublayer.
ENABLE; The interface employs the OAM sublayer and its functions.

local_oam_mode
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. Used to configure the OAM sublayer entity in either Active or Passive mode.
Values: PASSIVE; The OAM sublayer entity is configured in Passive mode.
ACTIVE; The OAM sublayer entity is configured in Active mode.

local_par_action
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This governs the flow of non-OAMPDUs within the Parser (See 57.3.4) function.
Values: FWD; Parser passes received non-OAMPDUs to superior sublayer.
LB; Parser passes received non-OAMPDUs to Multiplexer during remote loopback test.
DISCARD; Parser discards received non-OAMPDUs.

local_satisfied
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This indicates the OAM client finds the local and remote OAM configuration settings are agreeable.
Values: FALSE; OAM client either has not seen or is not satisfied with local and remote settings.
TRUE; OAM client is satisfied with local and remote settings.

local_stable
A variable set by the Discovery process. This is used to indicate local OAM client acknowledgment of and satisfaction with remote OAM state information.

Values: UNSTABLE; Indicates that local device either has not seen or is unsatisfied with remote state information.
STABLE; Indicates that local device has seen and is satisfied with remote state information.

local_time_stamp
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This indicates the current value of the OAM client time reference.
Value: Two-octet integer; cleared on (re-)initialization of OAM sublayer, incremented every 100ms.

local_tx
This is used to govern the transmission of OAMPDUs as part of the Discovery process.
Values: NONE; No OAMPDUs are allowed to be transmitted.
INFO; Only Information OAMPDUs are allowed to be transmitted.
ANY; Any permissible OAMPDU (See Table 57–1) is allowed to be transmitted.

local_unidirectional
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This indicates the device is capable of sending OAMPDUs when the link in the receive direction is not operational.
Values: FALSE; Device is unable to send OAMPDUs when receive path is not operational.
TRUE; Device is capable of sending OAMPDUs when receive path is not operational.

remote_stable
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. OAM client extracts remote state information from received Information OAMPDUs. This is used to indicate remote OAM client acknowledgment of and satisfaction with local OAM state information.
Values: UNSTABLE; Indicates that remote device either has not seen or is unsatisfied with local state information.
STABLE; Indicates that remote device has seen and is satisfied with local state information.

remote_state_valid
A parameter of the OAM_CTL.request primitive, as defined in 57.2.5.4. This is used to indicate OAM client has received remote state information contained within Information OAMPDUs.
Values: FALSE; Indicates that OAM client has not seen remote state information.
TRUE; Indicates that OAM client has seen remote state information.

req_DA
req_SA
req_mac_service_data_unit
req_frame_check_sequence
The parameters of the MA_DATA.request primitive, as defined in *CROSS REF* Clause 2.

57.3.1.3 Messages

MAC:MA_DATA.indication
Parser:MA_DATA.indication
The service primitives used to pass a received frame to a client with the specified parameters.

MADI
Alias for
MA_DATA.indication(ind_DA, ind_SA, ind_mac_service_data_unit, ind_reception_status)

MAC:MA_DATA.request
Control:MA_DATA.request
OAM:MA_DATA.request
The service primitives used to transmit a frame with the specified parameters.

MADR
Alias for
MA_DATA.request(req_DA, req_SA, req_mac_service_data_unit, req_frame_check_sequence)

OAM_CTL.indication
OAM_CTL.request
The service primitives used to convey information between the OAM sublayer entity and the OAM client.

RxOAMPDU
Alias for ind_DA = Slow_Protocols_Multicast * ind_Length/Type = Slow_Protocols_Type * ind_subtype = OAM_subtype

57.3.1.4 Counters

pdu_cnt
A counter reset by the OAMPDU Transmit state diagram and decremented by the Multiplexer state diagram. This is used to limit the number of OAMPDUs transmitted per second and ensure at least one OAMPDU is sent each second.

57.3.1.5 Timers

All timers operate in a manner consistent with 14.2.3.2.

local_lost_link_timer
Timer used to reset the Discovery process.
Duration: 5 s, tolerance +0 s, -0 s.

pdu_timer
Timer used to ensure OAM sublayer adheres to maximum number of OAMPDUs per second and emits at least one OAMPDU per second.
Duration: 1 s, tolerance +0 s, -0 s.

57.3.2 Control

The Control block contains the Discovery process and provides the interfaces with the OAM client to transmit and receive OAMPDUs.

57.3.2.1 Discovery

OAM provides a mechanism to detect the presence of an OAM sublayer at the remote device. This mechanism is called Discovery. OAM sublayer entities shall implement the Discovery state diagram shown in Figure 57–4.

After being enabled, a device configured in Active mode (See 57.2.6.1) sends Information OAMPDUs that only contain the Local Information TLV (See 57.5.2.1). This state is called ACTIVE_SEND_LOCAL. While in this state, the local device waits for Information OAMPDUs received from the remote device.

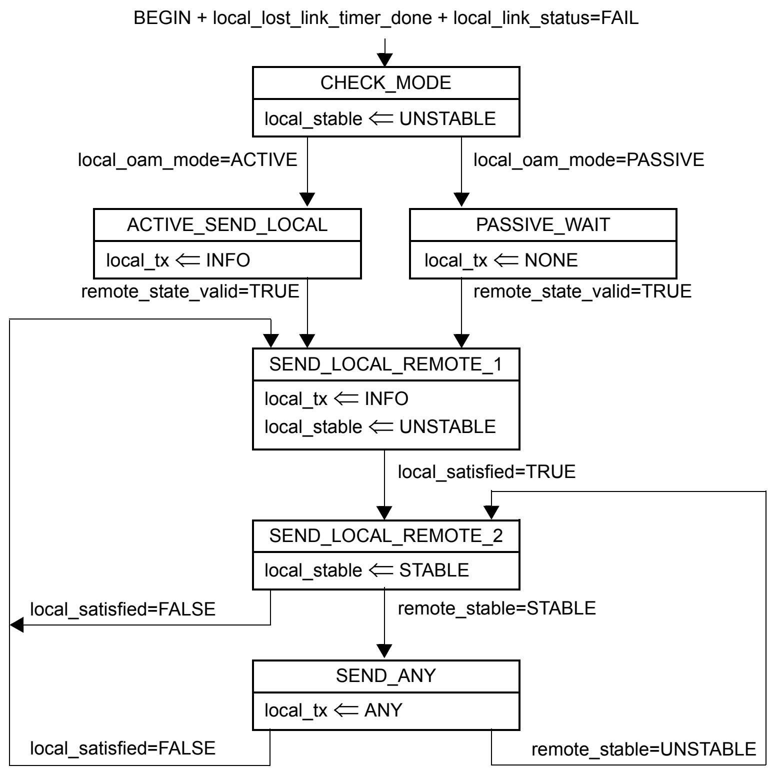

Figure 57–4—Discovery state diagram

A device configured in Passive mode (See 57.2.6.2) waits until receiving Information OAMPDUs before sending any Information OAMPDUs. This state is called PASSIVE_WAIT. By waiting until first receiving an Information OAMPDU, a passive device can not complete the Discovery process when connected to another passive device.

Once the local device has received an Information OAMPDU from the remote device, the local device begins sending Information OAMPDUs that contain both the Local and Remote Information TLVs. This state is called SEND_LOCAL_REMOTE_1. If management deems the settings on both the local and remote devices are acceptable, it enters the SEND_LOCAL_REMOTE_2 state. Once in the SEND_LOCAL_REMOTE_2 state, the local OAM client sends an Information OAMPDU with local and remote Information TLVs. Finally, once the remote device indicates that its management is satisfied with the respective settings, the local device enters the SEND_ANY state. During this state, the local device is permitted to send any OAMPDU.

If at any time the settings on either the local or remote change resulting in management becoming unsatisfied with the settings, the state machine returns to the SEND_LOCAL_REMOTE_1 state.

If at any time the settings on the local OAM client change resulting in management of the remote OAM client becoming unsatisfied with the settings, the state machine returns to the SEND_LOCAL_REMOTE_2 state.

If OAM is reset, disabled and re-enabled, the local_lost_link_timer expires or the local_link_status equals FAIL, the state machine returns to the CHECK_MODE state.

57.3.2.2 Transmit rules

The following rules govern the transmission of OAMPDUs:

a) The transmission of an OAMPDU shall not effect the transmission of a frame that has been submitted to the subordinate sublayer (i.e., the MAC's TransmitFrame function is synchronous, and is never interrupted).
b) While local_tx is set to NONE, OAMPDUs shall not be transmitted.
c) While local_tx is set to INFO, Information OAMPDUs shall only be transmitted. The rate of Information OAMPDUs is governed by the OAMPDU Transmit state diagram (Figure 57–5).
d) While local_tx is set to ANY, OAMPDU.request primitive requests the transmission of an OAMPDU. Transmission is governed by the OAMPDU Transmit state diagram (Figure 57–5).
e) While local_tx is set to INFO or ANY:
    1) OAM_CTL.request primitive with the local_dying_gasp, local_link_fault or local_critical_event parameter set enables the immediate transmission of Information OAMPDU with the appropriate bit set in the Flags field. This Information OAMPDU with critical events set in the Flags field is sent immediately and is not governed by Figure 57–5.
    2) As shown in Figure 57–5, in the absence of any transmitted OAMPDUs, an Information OAMPDU is sent every second to prevent the Discovery process from restarting.

57.3.2.3 Transmit state diagram

OAMPDU transmission shall be as shown in Figure 57–5. The OAMPDU Transmit state diagram monitors

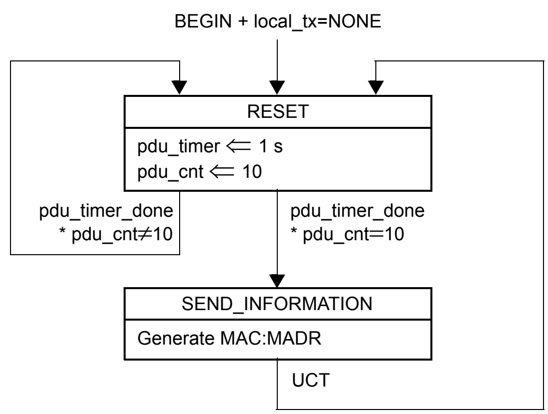

Figure 57–5—OAMPDU Transmit state diagram

the transmission of OAMPDUs and causes at least one OAMPDU to be sent each second thus preventing the Discovery process from restarting. It also allows variable intervals between OAMPDUs within a given second. The Multiplexer state diagram found in Figure 57–6 enforces the maximum number of OAMPDUs within a given second.

Once the Discovery process sets the local_tx variable to either INFO or ANY, the RESET state is entered. The pdu_timer is reset to one second and pdu_cnt is reset to ten. Once the pdu_timer has expired, pdu_cnt is evaluated. If equal to ten, meaning no OAMPDUs have been sent in the last second, the SEND_INFORMATION state is entered. Here, an Information OAMPDU will be transmitted to the remote device. This prevents the remote device's lost_link_timer from expiring this keeping the Discovery process from restarting. After sending the Information OAMPDU, the state machine returns to the RESET state.

If, however, the pdu_timer expires and the pdu_cnt is a value other than ten, this indicates one or more OAMPDUs have been transmitted within the last second. The state machine then simply transitions to the RESET state.

57.3.3 Multiplexer

The Multiplexer shall provide transparent pass-through of frames submitted by the superior sublayer and the Control function. The Multiplexer shall implement the function specified by the state diagram shown in Figure 57–5. The After reset, the Multiplexer state machine enters the WAIT_FOR_TX state. It waits for the

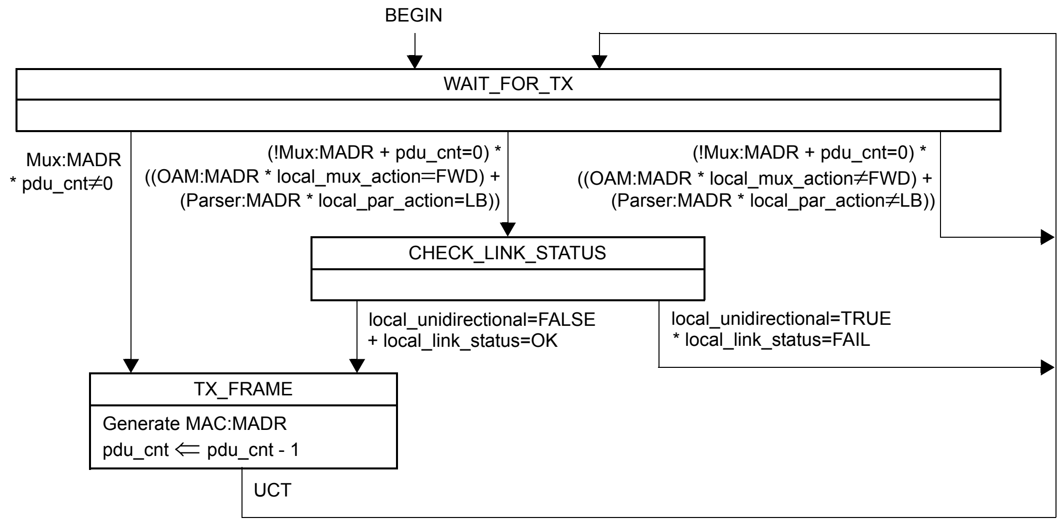

Figure 57–6—Multiplexer state diagram

request to transmit a frame as indicated by either an OAMPDU transmit request (Mux:MADR), a MAC Client transmit frame request (OAM:MADR) or a loopback transmit request (Parser:MADR).

When the Mux:MADR service primitive occurs, the Multiplexer will check pdu_cnt. This counter keeps track of the number of OAMPDUs transmitted within each second. If the pdu_cnt counter is non-zero, the TX_FRAME state is entered, the OAMPDU is transmitted and the pdu_cnt counter is decremented. The state machine returns to the WAIT_FOR_TX state. The OAMPDU Transmit state diagram (Figure 57–5) resets the pdu_cnt counter to ten each second. If the Mux:MADR service primitive occurs and the pdu_cnt counter is zero, the OAMPDU is discarded and the state machine returns to the WAIT_FOR_TX state.

Frames from the MAC Client are transmitted by the Multiplexer when the following conditions are present:

a) The OAM:MADR primitive occurs and no Mux:MADR primitive is detected (or a Mux:MADR primitive is detected but the maximum number of OAMPDUs transmitted per second has been reached),
b) The local_mux_action parameter is set to FWD, indicating neither the local nor the remote device is in remote loopback mode,
c) The local_unidirectional parameter is FALSE or the link_status parameter is OK. Since only OAMPDUs may be sent on a unidirectional link, the status of the link and the capability of the PHY is evaluated. When the local_unidirectional parameter is FALSE, the underlying PHY, when a valid link has not been established, will effectively discard the transmitted frame. This ensures the same behavior as PHYs that do not support the optional OAM Unidirectional capability. When the link_status parameter is OK the frame will be transmitted regardless of the PHY's OAM Unidirectional capability and setting.

Loopback frames from the Parser are transmitted by the Multiplexer when the following conditions are present:

a) The Parser:MADR primitive occurs and no Mux:MADR primitive is detected (or a Mux:MADR primitive is detected but the maximum number of OAMPDUs transmitted per second has been reached),
b) The local_par_action parameter is set to LB, indicating the local device is in remote loopback mode,

c) The local_unidirectional parameter is FALSE or the link_status parameter is OK. Since only OAMPDUs may be sent on a unidirectional link, the status of the link and the capability of the PHY is evaluated. When the local_unidirectional parameter is FALSE, the underlying PHY, when a valid link has not been established, will effectively discard the transmitted frame. This ensures the same behavior as PHYs that do not support the optional OAM Unidirectional capability. When the link_status parameter is OK the frame will be transmitted regardless of the PHY's OAM Unidirectional capability and setting.

Any of the following conditions will cause the Multiplexer to discard the requested transmit frame:

a) An OAMPDU is requested but the maximum number of OAMPDUs transmitted per second has been reached)
b) A MAC Client frame is requested but the local device is in remote loopback mode as indicated by the local_mux_action parameter set to DISCARD
c) A loopback frame is requested but the local device is not in remote loopback mode as indicated by the local_par_action parameter set to something other than LB
d) A non-OAMPDU is requested but only one direction of the link has been established and the underlying PHY is configured to be in OAM Unidirectional mode

57.3.3.1 Receive rules

The following rules govern the reception of OAMPDUs:

a) All validly formed, received OAMPDUs shall be passed to the OAM client entity.
b) All Parser:MADI primitives indicate an OAMPDU and in turn generate an OAMPDU.indication primitive to the OAM client entity.
c) The local_lost_link_timer is reset upon reception of any OAMPDU.
d) All requests have a maximum response time requirement (See 57.4).
e) The response rules are found in the definition of the OAMPDUs in 57.4 and are handled by the OAM client entity.

57.3.4 Parser

The Parser decodes frames received from the subordinate sublayer and passes OAMPDUs to the Control function. The Parser shall implement the function specified by the state diagram shown in Figure 57–7.

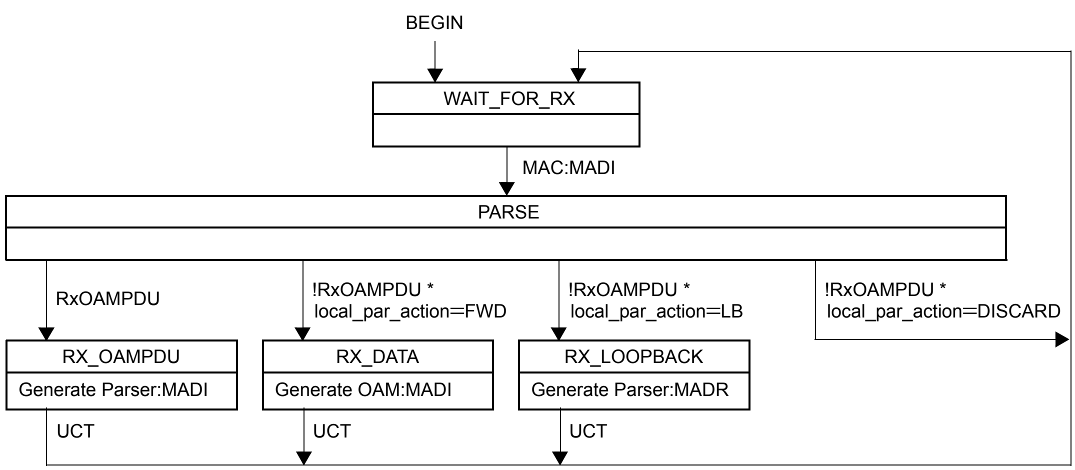

Figure 57–7—Parser state diagram

After reset, the Parser state machine enters the WAIT_FOR_RX state. The reception of a frame is detected when the MAC:MADI service primitive occurs. When a frame is received, the state machine enters the PARSE state.

The RX_OAMPDU state is entered when the receive frame is identified as an OAMPDU. Received OAMPDUs are sent to the OAM Control block via the Parser:MADI service primitive. The OAM Control block, per 57.3.3.1, then passes the received OAMPDU to the OAM client. The state machine then returns to the WAIT_FOR_RX state.

Received non-OAMPDUs are handled according to the setting of the local_par_action parameter. If the local_par_action parameter is set to FWD, the RX_DATA state is entered. The received frame is passed up to the superior sublayer via the OAM:MADI service primitive. If the local_par_action parameter is set to LB, the RX_LOOPBACK state is entered. The received loopback frame is passed to the Multiplexer block via the Parser:MADR service primitive to be looped back to the remote device. If the local_par_action parameter is set to DISCARD, the state machine returns to the WAIT_FOR_RX state. Refer to 57.2.8 for a complete description of remote loopback operation and the setting of the local_par_action parameter by the OAM client sublayer.

57.4 OAMPDUs

57.4.1 Transmission and representation of octets

All OAMPDUs comprise an integral number of octets. When the encoding of (an element of) an OAMPDU is depicted in a diagram:

a) Octets are transmitted from top to bottom.
b) Within an octet, bits are shown with bit 0 to the left and bit 7 to the right, and are transmitted from left to right.
c) When consecutive octets are used to represent a binary number, the octet transmitted first has the more significant value.
d) When consecutive octets are used to represent a MAC address, the least significant bit of the first octet is assigned the value of the first bit of the MAC address, the next most significant bit the value of the second bit of the MAC address, and so on for all the octets of the MAC address.

When the encoding of an element of an OAMPDU is depicted in a table:

e) Bits are transmitted from least significant (bit 0) to most significant.

57.4.2 Structure

OAMPDUs are basic IEEE 802.3 frames; they shall not be tagged (See *CROSS REF* Clause 3). The OAMPDU structure shall be as shown in Figure 57–8 and as further described in the following field defini-

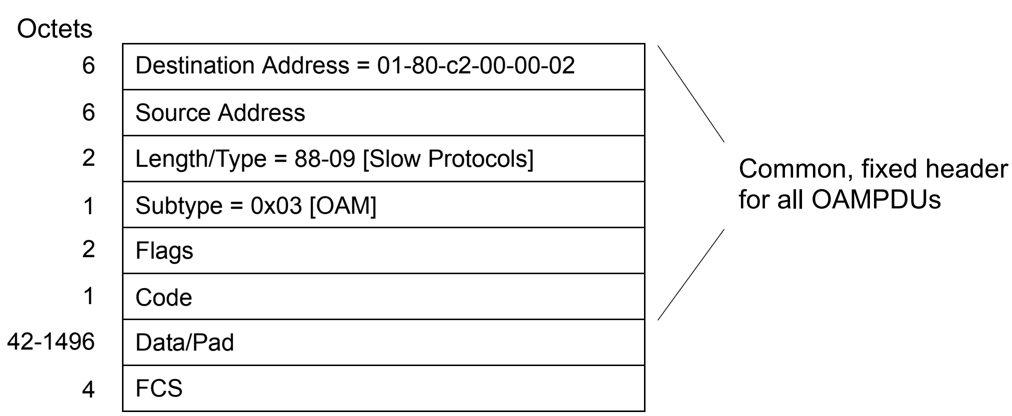

Figure 57–8—OAMPDU frame structure

tions:

a) ***Destination Address*** (DA). The DA in OAMPDUs is the Slow_Protocols_Multicast address. Its use and encoding are specified in *CROSS REF* Annex 43B.

b) ***Source Address*** (SA). The SA in OAMPDUs carries the individual MAC address associated with the port through which the OAMPDU is transmitted.

c) ***Length/Type***. OAMPDUs are always Type encoded, and carry the Slow_Protocols_Type field value. The use and encoding of this type is specified in *CROSS REF* Annex 43B.

d) ***Subtype***. The Subtype field identifies the specific Slow Protocol being encapsulated. OAMPDUs carry the Subtype value 0x03.

e) ***Flags***. The Flags field contains status bits as defined in 57.4.2.1.

f) ***Code***. The Code field identifies the specific OAMPDU. The use and encoding of this field is specified in Table 57–4.

g) ***Data/Pad***. This field contains the OAMPDU data and any necessary pad. Implementations shall support OAMPDUs at least minFrameSize in length.

h) ***FCS***. This field is the Frame Check Sequence, typically generated by the underlying MAC.

57.4.2.1 Flags field

The Flags field is encoded as individual bits within two octets as shown in Table 57–3. Additional diagnostic information may be sent using the Event Notification OAMPDU defined in 57.4.3.2.

Table 57–3—Flags field

Bit(s)	Name	Description
15:3	*Reserved*	Reserved field should be set to zero when sending an OAMPDU, and should be ignored on reception.
2	Critical Event	1 = A critical event has occurred 0 = A critical event has not occurred
1	Dying Gasp	1 = An unrecoverable local failure condition has occurred 0 = An unrecoverable local failure condition has not occurred
0	Link Fault	The PHY has detected a fault has occurred in the receive direction of the local device (e.g. link, Physical layer). 1 = Local device’s receive path is impaired 0 = Local device’s receive path is functional
Note: The definition of the specific faults comprising the Critical Event, Dying Gasp, and Link Fault flags is beyond the scope of this clause.		

57.4.2.2 Code field

The value of the Code field is set by the OAM Control block for Information OAMPDUs it generates. The OAM client sets the Code field for all OAMPDUs it generates. Table 57–4 contains the defined OAMPDU codes.

57.4.3 OAMPDU descriptions

The local OAM sublayer communicates with the remote OAM sublayer via OAMPDUs. OAMPDUs are identified with a specific code.

Table 57–4—OAMPDU Codes

Code	OAMPDU	Comment
00	Information	Communicates local and remote OAM information
01	Event Notification	Alerts remote device of link event(s)
02	Variable Request	Requests one or more specific 802.3 variables
03	Variable Response	Returns one or more specific 802.3 variables
04	Loopack Control	Enables/disables OAM remote loopback
05-FD	*Reserved*	*Reserved for future use*
FE	Organization Specific	Reserved for Organization Specific Extensions Distinguished by Organizationally Unique Identifier
FF	*Reserved*	*Reserved for future use*

All OAMPDUs contain a common, fixed header comprising the Destination Address, Source Address, Length/Type field, Subtype field, Flags field and Code field. The Data field begins in a fixed location within the OAMPDU. The Data field contents are unique to the particular OAMPDU. The following sections provide a detailed description of each OAMPDU and its corresponding Data field. All received OAMPDUs, including those with reserved codes, are passed to the OAM client.

57.4.3.1 Information OAMPDU

The Information OAMPDU, identified by the Code field 0x00, is used to send OAM state information to the remote device. The Information OAMPDU frame structure shall be as shown in Figure 57–9.

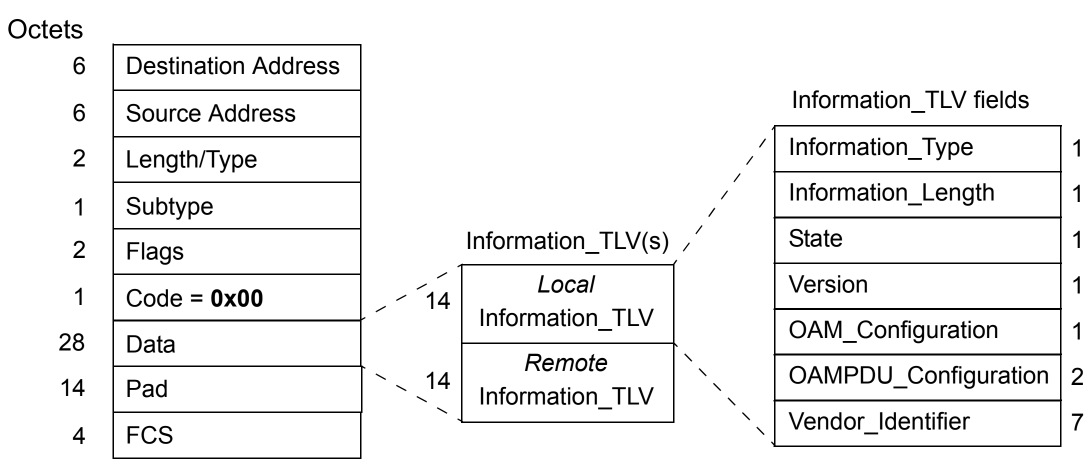

Figure 57–9—Information OAMPDU frame structure

The Information OAMPDU Data field, at a minimum, shall consist of the Local Information TLV containing local state and configuration information (See 57.5.2.1). If the Discovery state diagram variable remote_state_valid is TRUE, the Data field shall also contain the Remote Information TLV (See 57.5.2.2). The remaining octets of the Data field shall be set to zero.

57.4.3.2 Event Notification OAMPDU

The Event Notification OAMPDU, identified with the Code field set to 0x01, is used to alert the remote device of link events defined in 57.2.7.2. The Event Notification frame structure shall be as shown in Figure 57–10. The first two octets of the Data field shall contain an Event Sequence Number, encoded as a 16-bit

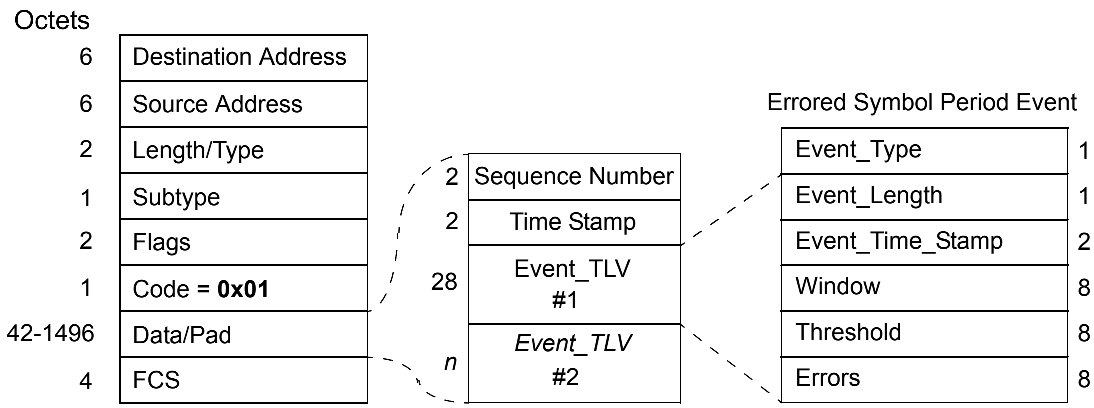

Figure 57–10—Event Notification OAMPDU frame structure

unsigned integer. As described in 57.2.3, the OAM client may send duplicate Event Notification OAMPDUs to increase the likelihood the remote device receives a particular event. The OAM client increments the Event Sequence Number for each unique Event Notification OAMPDU formed by the OAM client. A particular Event Notification OAMPDU may be sent multiple times with the same sequence number. Any particular event can be signaled in only one unique Event Notification OAMPDU (though that PDU may be transmitted multiple times). Upon receiving an Event Notification OAMPDU, the OAM client compares the sequence number with the last received Event Sequence Number. If equal, the current event is a duplicate is ignored by the OAM client.

Following the Event Sequence field, the Data field shall contain an Event Time Stamp field, encoded as a 16-bit unsigned integer. The Event Time Stamp provides a time reference that may be useful for the OAM client in reconstructing a time line of events.

Following the Event Sequence field, the Data field shall contain one or more Event TLVs which may provide useful information for troubleshooting events and faults. Event TLVs are defined in 57.5..

57.4.3.3 Variable Request OAMPDU

The Variable Request OAMPDU, identified with a Code field of 0x02, is used to request one or more IEEE 802.3 variables from the remote device. The Variable Request OAMPDU frame structure shall be as shown in Figure 57–11. The Variable Request OAMPDU Data field shall contain one or more Variable Descriptors. Variable Descriptors are defined in 57.6.1.

If a device receives a Variable Request from a passive peer, it shall respond with the Variable Error 0x07 indicating an illegal request from a Passive device as defined in Table 57–13..

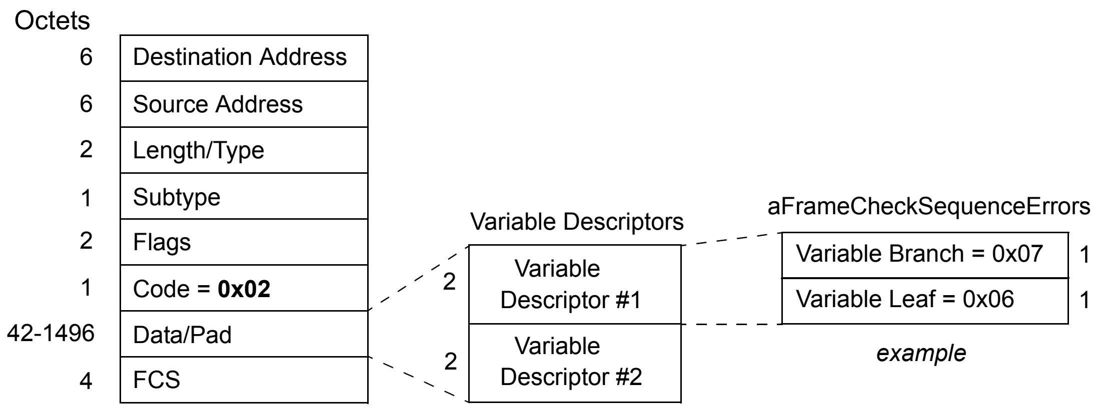

Figure 57–11—Variable Request OAMPDU frame structure

57.4.3.4 Variable Response OAMPDU

The Variable Response OAMPDU, identified with the Code field of 0x03, is used to return one or more IEEE 802.3 variables. The Variable Response OAMPDU frame structure shall be as shown in Figure 57–12.

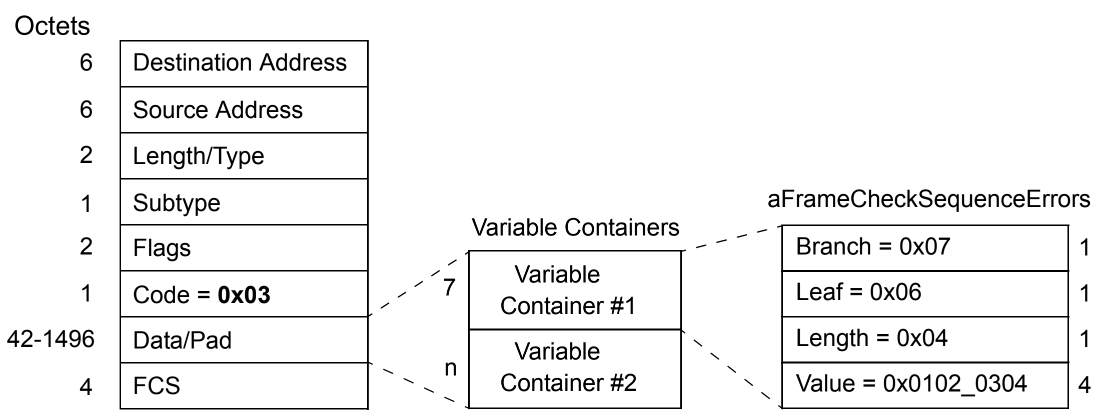

Figure 57–12—Variable Response OAMPDU frame structure

The Variable Response OAMPDU Data field shall contain one or more Variable Containers. Variable Containers are defined in 57.6.2. A Variable Response OAMPDU shall be sent by the OAM client within one second of receipt of a Variable Request OAMPDU. If a device is unable to retrieve one or more variables, it shall respond within one second and indicate the appropriate error(s) as found in Table 57–13. If a device is unable to retrieve one or more attributes within a package or object, is shall either a) return the appropriate Variable Error for the particular attribute(s) and return all other requested variables or b) return a Variable Error for the entire package or object.

57.4.3.5 Loopback Control OAMPDU

The Loopback Control OAMPDU, identified with the Code field set to 0x04, is used to control the remote device's loopback state. The Loopback Control OAMPDU frame structure shall be as shown in Figure 57–13. The Loopback Control OAMPDU Data field shall consist of a Loopback Command. Table 57–5 contains

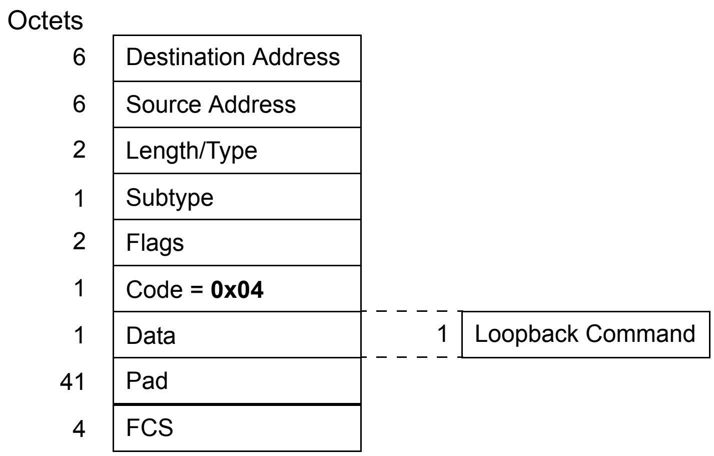

Figure 57–13—Loopback Control OAMPDU frame structure

the list of defined Loopback Commands. For a complete description of remote loopback refer to 57.2.8.

Table 57–5—Loopback Commands

Command	Description
0x00	*Reserved*
0x01	Enable Remote Loopback
0x02	Disable Remote Loopback
0x03-0xFF	*Reserved*

Devices shall ignore received Loopback Control OAMPDUs from remote devices in Passive mode.

57.4.3.6 Organization Specific OAMPDU

The Organization Specific OAMPDU, identified with the Code field set to 0xFE, is used for organization specific extensions. The Organization Specific OAMPDU frame structure shall be as shown in Figure 57–14. Organizations are distinguished by the Organizationally Unique Identifier administered by the IEEE. The first three octets of the Organization Specific OAMPDU Data field contains the 24-bit Organizationally

Unique Identifier. Refer to *CROSS REF* 22.2.4.3.1 for more information regarding the OUI. The remainder of the Data field is unspecified.

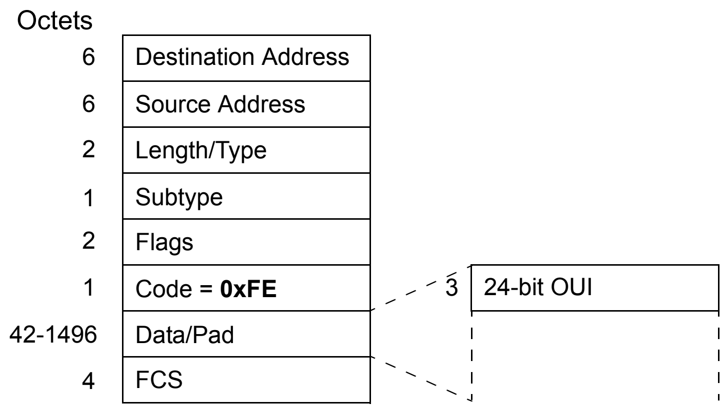

Figure 57–14—Organization Specific OAMPDU frame structure

57.5 OAM TLVs

57.5.1 Parsing

All OAM TLVs contain a single octet Type field and a single octet Length field. The Type field value 0x00 is reserved. The Length field encompasses the entire TLV, including the type, length and value fields. If a length of 0x00 or 0x01 is detected the current and subsequent TLVs shall be considered invalid and be ignored. When parsing TLVs within an OAMPDU, detection of a 0x00 octet immediately following a TLV indicates there are no more TLVs to parse.

There are two kinds of TLVs defined in this clause: Information TLVs used in Information OAMPDUs and Event TLVs found in Event Notification OAMPDUs.

57.5.2 Information TLVs

This subclause contains the definitions for Information TLVs. Information TLVs are found in Information OAMPDUs. Refer to 57.4.3.1 for a description of the Information OAMPDU and the usage of Information TLVs.

57.5.2.1 Local Information TLV

The Local Information TLV shall have the following fields:

a) ***Information_Type*** = *Local Information*. This one-octet field indicates the nature of the data carried in this TLV-tuple. Local Information TLVs are identified by the value 0x01.
b) ***Information_Length***. The one-octet field indicates the length (in octets) of this TLV-tuple. Local OAM Information TLV uses a length value of 14 (0x0e).
c) ***State***. This two-octet field contains OAM state information and shall be as shown in Table 57–6.
d) ***Version***. This one-octet field indicates the version supported by the device. This field shall contain the value 0x01 to claim compliance with Version 1 of this protocol.
e) ***OAM_Configuration***. This one-octet field contains OAM configuration variables and shall be as shown in Table 57–7.
f) ***OAMPDU_Configuration***. This two-octet field contains OAMPDU configuration variables and shall be as shown in Table 57–8.

Table 57–6—State field

Bit(s)	Name	Description
7:4	*Reserved*	Reserved field shall be set to zero when sending an OAMPDU, and shall be ignored on reception.
3	Multiplexer Action	When bit 3 = 0, [FWD]; indicates the device is forwarding non-OAMPDUs to the subordinate sublayer. When bit 3 = 1, [DISCARD]; indicates the device is discarding non-OAMPDUs.
2:1	Parser Action	When bits 2:1 = 0x0, [FWD]; indicates the device is forwarding non-OAMPDUs to the superior sublayer. When bits 2:1 = 0x1, [LB]; indicates the device is looping back non-OAMPDUs to the subordinate sublayer. When bits 2:1 = 0x2, [DISCARD]; indicates the device is discarding non-OAMPDUs received from subordinate sublayer. The value 0x3 shall not be sent.
0	Stable	When bit 0 = 0, [UNSTABLE]; indicates that the device either has not seen or is unsatisfied with remote state information. When bit 0 = 1, [STABLE]; indicates that the device has seen and is satisfied with remote state information.

Table 57–7—OAM_Configuration field

Bit(s)	Name	Description
7:3	*Reserved*	Reserved field shall be set to zero when sending an OAMPDU, and shall be ignored on reception.
2	Loopback_Support	1 = Device is capable of OAM loopback mode 0 = Device is not capable of OAM loopback mode
1	Unidirectional_Support	1 = Device is capable of sending OAMPDUs when the receive path is non-operational 0 = Device is not capable of sending OAMPDUs when the receive path is non-operational
0	OAM_Mode	See 57.2.6 for a complete description of OAM modes. 1 = Active mode 0 = Passive mode

g) ***Vendor Identifier***. This seven-octet field contains the Vendor Identifier variables and shall be as shown in Table 57–9. The fields of the Vendor Identifier provide context and definition for the vendor specific (0x80-0xFF) Event TLV space.

57.5.2.2 Remote Information TLV

The Remote Information TLV shall have the following fields:

Table 57–8—OAMPDU_Configuration field

Bit(s)	Name	Description
15:11	*Reserved*	Reserved field shall be set to zero when sending an OAMPDU, and shall be ignored on reception.
10:0	Maximum_PDU_Size	11-bit field which represents the largest OAMPDU, in octets, supported by the device. This value is compared to the remote's Maximum_PDU_Size and the smaller of the two is used. Prior to exchanging and agreeing upon a Maximum_PDU_Size, a device sends minFrameSize OAMPDUs. The minimum value is minFrameSize / 8. The maximum value is equal to maxUntaggedFrameSize which is defined in *CROSS REF* 4.4.2.

Table 57–9—Vendor_Identifier field

Bit(s)	Name	Description
55:40	Version_Identifier	16-bit version identifier which can be used to distinguish between versions of a particular vendor's products.
39:24	Device_Identifier	16-bit device identifier which can be used to differentiate a vendor's products.
23:0	OUI[a]	24-bit Organizationally Unique Identifier

[a]Interested applicants should contact the IEEE Standards Department, Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

a) ***Information_Type*** = *Remote Information*. This one-octet field indicates the nature of the data carried in this TLV-tuple. Remote Information TLVs are identified by the value 0x02.
b) ***Information_Length***. The one-octet field indicates the length (in octets) of this TLV-tuple. OAM_Information TLVs use a length value of 14 (0x0E).
c) ***State***. This one-octet field contains OAM state information and shall be as shown in Table 57–6.
d) **Version**. This one-octet field indicates the version supported by the device. This field shall contain the value 0x01 to claim compliance with Version 1 of this protocol.
e) ***OAM_Configuration***. This one-octet field contains OAM configuration variables and shall be as shown in Table 57–7.
f) ***OAMPDU_Configuration***. This two-octet field contains OAMPDU configuration variables and shall be as shown in Table 57–8.
g) ***Vendor_Identifier***. This seven-octet field contains the Vendor Identifier variables and shall be as shown in Table 57–9. The fields of the Vendor Identifier provide context and definition for the vendor specific (0x80-0xFF) Event TLV space.

57.5.3 Event TLVs

This subclause contains the definitions for Event TLVs. Event TLVs are found in Event Notification OAMPDUs. Table 57–10 describes the ranges of the Event TLV Type field. The following sub-clauses contain the defined Event TLVs. The vendor specific event range is specific to the Vendor Identification exchanged during the Discovery process. Multiple vendors may use the same event type with disparate definitions.

Table 57–10—Event TLV Type ranges

Type	Description
0x00	*Reserved*
0x01-0x7F	Defined by OAM
0x80-0xFF	Reserved for Vendor Specific

57.5.3.1 Errored Symbol Period Event TLV

The Errored Symbol Period Event TLV shall have the following fields:

a) ***Event_Type*** = *Errored Symbol Period Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. Errored Symbol Period Event is identified by the value 0x01.
b) ***Event_Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Symbol Period Event uses a length value of 28 (0x1C).
c) ***Event_Time_Stamp.*** This two-octet field indicates the time reference when the event was generated, encoded as a 16-bit unsigned integer.
d) ***Errored_Symbol_Window***. This field indicates the number of symbols in the period, encoded as a 64-bit unsigned integer.
    1) The default value is the number of symbols in one second for the underlying physical layer.
    2) The lower bound is the number of symbols in one second for the underlying physical layer.
    3) The upper bound is the number of symbols in one minute for the underlying physical layer.
e) ***Errored_Symbol_Threshold***. This eight-octet field indicates the number of errored symbols in the period that is required to be equal to or greater than in order for the event to be generated, encoded as a 64-bit unsigned integer.
    1) The default value is zero symbol errors.
    2) The lower bound is zero symbol errors.
    3) The upper bound is unspecified.
f) ***Errored_Symbols***. This eight-octet field indicates the number of symbol errors in the period, encoded as a 64-bit unsigned integer.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.2 Errored Frame Seconds Event TLV

Errored frames are detected at the Media Access Control sublayer and communicated via the reception_status paramter of the MA_DATA.indication service primitive. Per *CROSS REF* Figure 4-4b, errored frames are defined as either:

a) a frame that is too short (length less than minFrameSize octets),
b) a frame that is too long (length greater than maxUntaggedFrameSize if untagged or greater than maxUntaggedFrameSize + qTagPrefixSize if tagged),
c) a frame containing an invalid Frame Check Sequence,
d) a frame containing an invalid Length/Type field.

An errored frame second is a one second interval wherein at least one frame error has occurred. The Errored Frame Seconds Event TLV shall have the following fields:

a) ***Event_Type*** = *Errored Frame Seconds Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. Errored Frame Seconds Event is identified by the value 0x02.
b) ***Event_Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Frame Seconds Event uses a length value of 14 (0x0E).

c) ***Event_Time_Stamp.*** This two-octet field indicates the time reference when the event was generated, encoded as a 16-bit unsigned integer.
d) ***Errored_Frame_Window***. This two-octet field indicates the duration of period in terms of 100ms intervals, encoded as a 16-bit unsigned integer.
   1) The default value is one second.
   2) The lower bound is one second.
   3) The upper bound is one minute.
e) ***Errored_Frame_Threshold***. This four-octet field indicates the number of errored frames in the period that is required to be equal to or greater than in order for the event to be generated, encoded as a 32-bit unsigned integer.
   1) The default value is zero frame errors.
   2) The lower bound is zero frame errors.
   3) The upper bound is unspecified.
f) ***Errored_Frames***. This four-octet field indicates the number of frame errors in the period, encoded as a 32-bit unsigned integer.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.3 Errored Frame Period Event TLV

Refer to 57.5.3.2 for a description of errored frames. The Errored Frame Period Event TLV shall have the following fields:

a) ***Event_Type*** = *Errored Frame Period Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. Errored Frame Period Event is identified by the value 0x03.
b) ***Event_Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Frame Period Event uses a length value of 16 (0x10).
c) ***Event_Time_Stamp.*** This two-octet field indicates the time reference when the event was generated, encoded as a 16-bit unsigned integer.
d) ***Errored_Frame_Window***. This four-octet field indicates the duration of period in terms of frames, encoded as a 32-bit unsigned integer.
   1) The default value is the number of minFrameSize frames that can be received in one second on the underlying physical layer.
   2) The lower bound is the number of minFrameSize frames that can be received in one second on the underlying physical layer.
   3) The upper bound is the number of minFrameSize frames that can be received in one minute on the underlying physical layer.
e) ***Errored_Frame_Threshold***. This four-octet field indicates the number of errored frames in the period that is required to be equal to or greater than in order for the event to be generated, encoded as a 32-bit unsigned integer.
   1) The default value is zero frame errors.
   2) The lower bound is zero frame errors.
   3) The upper bound is unspecified.
f) ***Errored_Frames***. This four-octet field indicates the number of frame errors in the period, encoded as a 32-bit unsigned integer.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.4 Errored Frame Seconds Summary Event TLV

Refer to 57.5.3.2 for a description of errored frames. The Errored Frame Seconds Summary Event TLV shall have the following fields:

a) ***Event_Type*** = *Errored Frame Seconds Summary Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. Errored Frame Seconds Summary Event is identified by the value 0x04.

b) ***Event_Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Frame Seconds Summary Event uses a length value of 10 (0x0A).
c) ***Event_Time_Stamp.*** This two-octet field indicates the time reference when the event was generated, encoded as a 16-bit unsigned integer.
d) ***Errored_Frame_Seconds_Window***. This two-octet field indicates the duration of the period in terms of 100ms intervals, encoded as a 16-bit unsigned integer.
   1) The default value is 60 seconds.
   2) The lower bound is 10 seconds.
   3) The upper bound is 900 seconds.
e) ***Errored_Frame_Seconds_Threshold***. This two-octet field indicates the number of errored frame seconds in the period that is required to be equal to or greater than in order for the event to be generated, encoded as a 16-bit unsigned integer.
   1) The default value is zero errored seconds.
   2) The lower bound is zero errored seconds.
   3) The upper bound is unspecified.
f) ***Errored_Frame_Seconds***. This two-octet field indicates the number of errored frame seconds in the period, encoded as a 16-bit unsigned integer.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.5 Vendor Specific Event TLVs

Vendor Specific Event TLVs shall have the following fields:
a) ***Event_Type*** = *Vendor Specific Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. Vendor Specific Events are identified by having a value in the range of 0x80-0xFF, inclusive.
b) ***Event_Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. The length of the Vendor Specific Events is unspecified.
c) ***Vendor_Specific_Value***. This field indicates the value of the Vendor Specific Event. This field's length and contents and are unspecified.

57.6 Variables

IEEE 802.3 MIB variables are queried through the use of Variable Request OAMPDUs and returned through the use of Variable Response OAMPDUs. Variables are requested via a data structure called a Variable Descriptor and are returned through the use of a data structure called a Variable Container. The following sections describe the format of Variable Descriptors and Variable Containers.

57.6.1 Variable Descriptors

A Variable Descriptor is used to identify IEEE 802.3 attributes, objects and packages and uses the CMIP protocol encodings as found in *CROSS REF* Annex 30A. The Variable Descriptor structure shall be as shown in Table 57–11.

57.6.2 Variable Containers

Variable Containers are used to convey IEEE 802.3 attributes, objects and packages. The Variable Container structure shall be as shown in Table 57–12.

57.7 Examples

The following sections show examples of Variable Branches, Leaves, Descriptors and Containers.

Table 57–11—Variable Descriptor format

Bit(s)	Name	Description
7:0	Variable Branch	Derived from the CMIP protocol encodings in *CROSS REF* Annex 30A, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
15:8	Variable Leaf	The Variable Leaf field is derived from the CMIP protocol encodings in *CROSS REF* Annex 30A

Table 57–12—Variable Container format

Bit(s)	Name	Description
7:0	Variable Branch	Derived from the CMIP protocol encodings in *CROSS REF* Annex 30A, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
15:8	Variable Leaf	The Variable Leaf field is derived from the CMIP protocol encodings in *CROSS REF* Annex 30A
23:16	Variable Width	When bit 23 = 1, bits 22:16 represent a Variable Error Indication. Refer to Table 57–13 for the encoding of bits 22:16. There is no Variable Value field when bit 23 = 1. When bit 23 = 0, bits 22:16 represent the length of the Variable Value field in octets. An encoding of 0x00 equals 128 octets. All other encodings represent actual lengths.
varies	Variable Value	The Variable Value field may be 1 to 128 octets in length. Its width is determined by the Variable Width field.

57.7.1 Variable Branch/Leaf examples

Table 57–13—Variable Error Indications

Coding	Error Indication
0x00	*Reserved needs update*
0x01	Requested variable was unable to be returned due to an undetermined error.
0x02	Requested variable was unable to be returned as the requested variable is not supported by the local device.
0x03	Requested variable experienced an overflow error.
0x04	Length of requested variable container(s) exceeded OAMPDU data field.
0x05	Requested variable may have been corrupted due to reset.
0x06	Requested variable unable to be returned due to a hardware failure.
0x07	Illegal request from device in Passive mode.
0x0-7F	*Reserved needs update*

Table 57–14—Variable Branch/Leaf Examples

Variable Type	Variable Name	Variable Branch	Variable Leaf
attribute	aFramesTransmittedOK	0x07	0x02
attribute	aFramesReceivedOK	0x07	0x05
attribute	aFrameCheckSequenceErrors	0x07	0x06
attribute	aOctetsTransmittedOK	0x07	0x08
attribute	aOctetsReceivedOK	0x07	0x0E
package	pMandatory	0x04	0x01
package	pRecommended	0x04	0x02
package	pOptional	0x04	0x03
object	oMACEntity	0x03	0x01
object	oPHYEntity	0x03	0x02
object	oMACControlEntity	0x03	0x08

57.8 Protocol Implementation Conformance Statement (PICS) proforma for Clause 57, Operations, Administration and Maintenance (OAM)[1]

57.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 57, Operations, Administration and Maintenance (OAM), shall complete the following Protocol Implementation Conformance Statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

[1]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

57.8.2 Identification

57.8.2.1 Implementation identification

Supplier	
Contact point for enquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTES 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

57.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3ah-2004, Clause 57, Operations, Administration and Maintenance (OAM)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to the standard.)	

Date of Statement	

57.8.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OM	OAM object class	*CROSS REF* 30.11		O	Yes [ ] No [ ]
*CSI	OAM client service interfaces	57.2.5.1		M	Yes [ ] No [ ]
*PASS	Passive mode	57.2.6		O	Yes [ ] No [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
*LB	Remote loopback	57.1.2		O	Yes [ ] No [ ]
*UNI	Unidirectional operation	57.1.2		O	Yes [ ] No [ ]

57.8.3 PICS proforma Tables for Operation, Administration and Maintenance (OAM)

57.8.3.1 Functional Specifications

Item	Feature	Subclause	Value/Comment	Status	Support
OFS1	Disable or (re-)enable of local_oam_enable	57.2.5.4.2	Resets OAM sublayer	M	Yes [ ] No [ ]
OFS2	OAMPDU.request primitive	57.2.5.2.3	Generated whenever OAMPDU is sent to peer entity	M	Yes [ ] No [ ]
OFS3	Passive mode limited transmission	57.2.6.2	Cannot send Variable Request or Loopback Control OAMPDUs	PASS:M	Yes [ ] No [ ] N/A [ ]
OFS4	OAMPDU transmission	57.3.2.2	Only when local_tx is set to INFO or ANY	M	Yes [ ] No [ ]
OFS5	Effect of OAMPDU on a frame already submitted to subordinate sublayer	57.3.2.2	Has no effect	M	Yes [ ] No [ ]
OFS6	Information OAMPDU transmitted at least once per second	57.3.2.3		M	Yes [ ] No [ ]
OFS7	All validly-formed, received OAMPDUs are sent to OAM client entity	57.3.3.1		M	Yes [ ] No [ ]
OFS8	Discovery state diagram	57.3.2.1	Implemented as defined in Figure 57–4	M	Yes [ ] No [ ]
OFS9	OAMPDU Transmit state diagram	57.3.2.3	Implemented as defined in Figure 57–5	M	Yes [ ] No [ ]
OFS10	Multiplexer state diagram	57.3.3	Implemented as defined in Figure 57–6	M	Yes [ ] No [ ]
OFS11	Multiplexer	57.3.3	Provide transparent pass-through of frames from superior sublayer to subordinate sublayer	M	Yes [ ] No [ ]
OFS12	Unidirectional link	57.3.3	Only OAMPDUs may be transmitted	UNI:M	Yes [ ] No [ ] N/A [ ]
OFS13	Unidirectional link	57.3.3	MAC Client frames are discarded	UNI:M	Yes [ ] No [ ] N/A [ ]
OFS14	Remote loopback	57.3.3	Only OAMPDUs and loopback frames may be sent	LB:M	Yes [ ] No [ ] N/A [ ]
OFS15	Remote loopback	57.3.3	MAC Client frames are discarded	LB:M	Yes [ ] No [ ] N/A [ ]
OFS16	Parser state diagram	57.3.4	Implemented as defined in Figure 57–7	M	Yes [ ] No [ ]

57.8.3.2 Event Notification Generation and Reception

Item	Feature	Subclause	Value/Comment	Status	Support
CEV1	Critical Event generation	57.2.7.3	Generated by OAM_CTL.request primitive	M	Yes [ ] No [ ]
CEV2	Critical Event reception	57.2.7.4	Indicated via OAM_CTL.indication primitive	M	Yes [ ] No [ ]
LEV1	Link Event reception	57.2.7.4	Indicated via OAMPDU.indication primitive with all received Event Notification OAMPDUs	M	Yes [ ] No [ ]

57.8.3.3 Remote loopback timing considerations

Item	Feature	Subclause	Value/Comment	Status	Support
LS1	Delay from receiving valid Loopback Control OAMPDU with Enable Remote Loopback command, to transmission of loopback frames	57.2.8.6	Delay at MDI ≤ 1s	LB:M	Yes [ ] No [ ]
LS2	Delay from receiving valid Loopback Control OAMPDU with Enable Remote Loopback command, to transmission of Information OAMPDU with non-zero loopback timer and local_action set to LB	57.2.8.6	Delay at MDI ≤ 1s	LB:M	Yes [ ] No [ ]
LE1	Delay from receiving valid Loopback Control OAMPDU with Disable Remote Loopback command, to transmission of Information OAMPDU with local_action set to FWD	57.2.8.6	Delay at MDI ≤ 1s	LB:M	Yes [ ] No [ ]
LE2	Delay from receiving valid Loopback Control OAMPDU with Disable Remote Loopback command, to transmission of MAC Client frames	57.2.8.6	Delay at MDI ≤ 1s	LB:M	Yes [ ] No [ ]

57.8.3.4 OAMPDUs

Item	Feature	Subclause	Value/Comment	Status	Support
PDU1	Tagging	57.4.2	OAMPDUs cannot be tagged	M	Yes [ ] No [ ]
PDU2	OAMPDU structure	57.4.2	As defined in Figure 57–8 and field definitions	M	Yes [ ] No [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
PDU3	Minimum OAMPDU size	57.4.2	Support at least 64 octet OAMPDUs	M	Yes [ ] No [ ]
PDU4	Information OAMPDU	57.4.3.1	Consist of Information TLV containing local state and configuration information	M	Yes [ ] No [ ]
PDU5	Information OAMPDU	57.4.3.1	Data field’s remaining octets set to zero	M	Yes [ ] No [ ]
PDU6	Event Notification OAMPDU	57.4.3.2	Data field contains a time stamp encoded as 16-bit integer	M	Yes [ ] No [ ]
PDU7	Event Notification OAMPDU	57.4.3.2	Data field contains a sequence number encoded as 16-bit integer, following the time stamp	M	Yes [ ] No [ ]
PDU8	Event Notification OAMPDU	57.4.3.2	Data field containing one or more Event TLVs following the sequence number	M	Yes [ ] No [ ]
PDU9	Variable Request OAMPDU	57.4.3.3	Data field contains one or more Variable Descriptors	!PASS: M	Yes [ ] No [ ] N/A [ ]
PDU10	Variable Response OAMPDU	57.4.3.4	Data field contains one or more Variable Containers	M	Yes [ ] No [ ]
PDU11	Variable Response OAMPDU timing consideration	57.4.3.4	Variable Response OAMPDU sent within one second of Variable Request OAMPDU reception	M	Yes [ ] No [ ]
PDU12	Variable Response OAMPDU timing consideration when error(s) encountered	57.4.3.4	Variable Response OAMPDU sent with error as defined in Table 57–13 within one second of Variable Request OAMPDU reception	M	Yes [ ] No [ ]
PDU13	Loopback Control OAMPDU	57.4.3.5	Data field contains a single Loopback Command from Table 57–5 followed by zeroes.	!PASS * LB:M	Yes [ ] No [ ] N/A [ ]
PDU14	Organization Specific OAMPDU	57.4.3.6	Data field contains the Organizationally Unique Identifier encoded as a 24-bit unsigned integer	O	Yes [ ] No [ ]

57.8.3.5 Information TLVs

Item	Feature	Subclause	Value/Comment	Status	Support
IT1	Information TLV	57.5.2.1	Contains the following fields: Information_Type, Information_Length, State, Version, OAM_Configuration, OAMPDU_Configuration, Vendor_Identifier	M	Yes [ ] No [ ]
IT2	Information TLV State field	57.5.2.1	As defined in Table 57–6	M	Yes [ ] No [ ]
IT3	Information TLV Version field	57.5.2.1	Contains 0x01 to claim compliance to this specification	M	Yes [ ] No [ ]
IT4	Information TLV OAM_Configuration field	57.5.2.1	As defined in Table 57–7	M	Yes [ ] No [ ]
IT5	Information TLV OAMPDU_Configuration field	57.5.2.1	As defined in Table 57–8	M	Yes [ ] No [ ]
IT6	Information TLV Vendor_Identifier field	57.5.2.1	As defined in Table 57–9	M	Yes [ ] No [ ]

57.8.4 Event TLVs

Item	Feature	Subclause	Value/Comment	Status	Support
ET1	Errored Symbol Period Event TLV	57.5.3.1	Contains the following fields: Event_Type, Event_Length, Time Stamp, Errored_Symbol_Window, Errored_Symbol_Threshold, Errored_Symbols	M	Yes [ ] No [ ]
ET2	Errored Frame Seconds Event TLV	57.5.3.2	Contains the following fields: Event_Type, Event_Length, Event_Time_Stamp, Errored_Frame_Window, Errored_Frame_Threshold, Errored_Frames	M	Yes [ ] No [ ]
ET3	Errored Frame Period Event TLV	57.5.3.3	Contains the following fields: Event_Type, Event_Length, Time Stamp, Errored_Frame_Window, Errored_Frame_Threshold, Errored_Frames	M	Yes [ ] No [ ]
ET4	Errored Frame Seconds Summary Event TLV	57.5.3.4	Contains the following fields: Event_Type, Event_Length, Time Stamp, Errored_Frame_Seconds_Window, Errored_Frame_Seconds_Threshold, Errored_Frame_Seconds	M	Yes [ ] No [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
ET5	Vendor Specific Event TLV	57.5.3.5	Contains the following fields: Event_Type, Vendor_Specific_Length, Vendor_Specific_Value	O	Yes [ ] No [ ]

57.8.5 Variables Descriptors and Containers

Item	Feature	Subclause	Value/Comment	Status	Support
VAR1	Variable Descriptor structure	57.6.1	As defined in Table 57–11	O	Yes [ ] No [ ]
VAR2	Variable Branch	57.6.1	If an object or package is referenced, only the attribute within the object or package can be found within a Variable Descriptors	M	Yes [ ] No [ ]
VAR3	Variable Branch	57.6.1	Actions are not found in Variable Descriptors	M	Yes [ ] No [ ]
VAR4	Variable Container structure	57.6.2	As defined in Table 57–12	O	Yes [ ] No [ ]
VAR5	Variable Branch	57.6.2	If an object or package is referenced, only the attribute within the object or package can be found within a Variable Container	M	Yes [ ] No [ ]
VAR6	Variable Branch	57.6.2	Actions are not found in Variable Containers	M	Yes [ ] No [ ]

58. Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10 and 1000BASE-PX20 (long wavelength passive optical networks)

Editors' Notes: *To be removed prior to final publication.*
*2. *ref* is intended to highlight references outside of this clause that will be adjusted prior to publication*
3. 58.3.4 - PMD Signal detect definition is included as text from previous clauses. This text may change per the resolution of signal detct for PON application.
4. Table 58–6 and Table 58–9 may be replaced by a set of curves at final publication

References:
ANSI/EIA/TIA-455-127, currently [B8] of annex A.

Definitions (to be added to 1.4):
T_Optical_rec_recovery is the sum of receiver recovery time and level recovery time. It is defined as the time interval between receiving a valid optical level and a valid electrical output at TP4.

Abbreviations (to be added to 1.5):
ODN - Optical Distribution Network
PON - Passive Optical Network

Revision History:

Draft 0.9 June 2002	Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.0 August 2002	Draft 1.0 for IEEE P802.3ah Task Force review
Draft 1.1 October 2002	Draft 1.1 for IEEE P803.3ah Task Force review
Draft 1.2 November 2002	Draft 1.2 for IEEE P802.3ah Task Force review
Draft 1.3 January 2003	Draft 1.3 for IEEE P802.3ah Task Force review
Draft 1.414 April 2003	Draft 1.3 for IEEE P802.3ah Task Force review

58.1 Overview

The 1000BASE-PX10 and 1000BASE-PX20 PMD sublayers provide point-to-multipoint 1000 Mb/s Ethernet connections over Passive Optical Networks (PON) up to 10 km and 20 km long, respectively. In an Ethernet passive optical network, a single "D" PMD broadcasts to a number of "U" PMDs and receives bursts from each "U" PMD over a single mode fiber network of branching topology. The same fibers are used in both directions. This clause specifies the 1000BASE-PX10-D PMD, 1000BASE-PX10-U PMD, 1000BASE-PX20-D PMD and the 1000BASE-PX20-U PMD (including MDI) and the medium, single-mode fiber. In order to form a complete physical layer, a PMD shall be integrated with the 1000BASE-X PCS and PMA of Clause 36, and optionally integrated with the management functions which may be accessible through the management interface defined in Clause 22*ref* or 45*ref*, which are hereby incorporated by reference.

A 1000BASE-PX10 link uses a 1000BASE-PX10-U PMD at one end and a 1000BASE-PX10-D PMD at the other. A 1000BASE-PX20 link uses a 1000BASE-PX20-U PMD at one end and a 1000BASE-PX20-D PMD at the other. Typically, the 1490 nm band is used to transmit away from the center of the network ("downstream") and the 1310 nm band towards the center ("upstream"). The suffixes "D" and "U" indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions.

Two optional temperature ranges are defined; see Annex 66A*ref* for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

Table 58–1 shows the primary attributes of each PMD type

58.1.1 Goals and Objectives

Support subscriber access network topologies:

Point to multipoint on optical fiber

Such that:

Provide a family of physical layer specifications:

PHY for PON, ≥ 10km, 1000Mbps, single SM fiber, ≥ 1:16

PHY for PON, ≥ 20km, 1000Mbps, single SM fiber, ≥ 1:16

Optical EFM PHYs to have a BER better than or equal to 10^{-12} at the PHY service interface

> ***Editors' Note:*** *To be removed prior to final publication.*
> *This subclause on Goals and Objectives will be removed prior to publication*

58.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 58–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

58.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

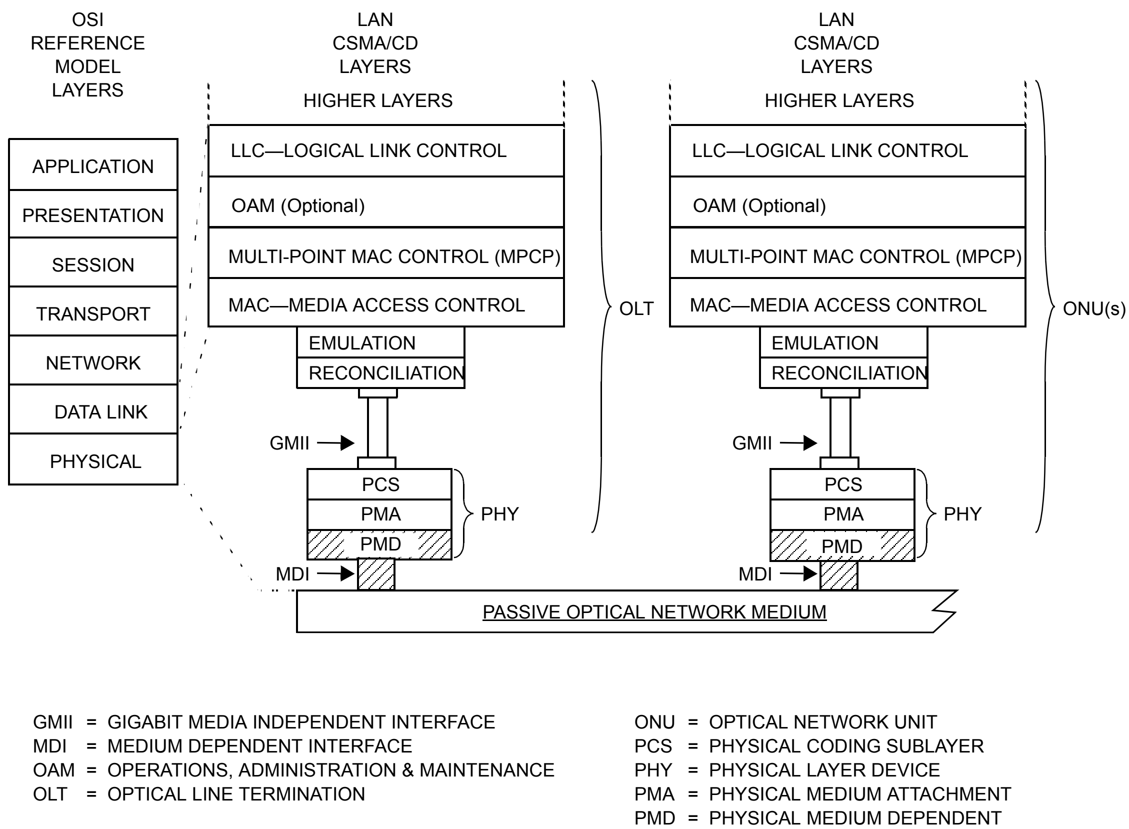

Figure 58–1—Architectural positioning of EFM: P2MP Topologies

Table 58–1—PMD types specified in this Clause

Description	1000BASE-PX10-U	1000BASE-PX10-D	1000BASE-PX20-U	1000BASE-PX20-D	Unit
Fiber type	B1.1, B1.3 SMF				
Number of fibres	1				
Nominal transmit wavelength	1310	1490	1310	1490	nm
Transmit direction	Upstream	Downstream	Upstream	Downstream	
Minimum range	0.5 m to 10 km		0.5 m to 20 km		km
Maximum channel insertion loss[a]	20	19.5	24	23.5	dB
Minimum channel insertion loss	5		10		dB

[a]at the nominal operating wavelength

Basic terminology and conventions, see Clause 1.1*ref* and Clause 1.2*ref*.

Normative references, see Clause 1.3*ref*.

Definitions, see Clause 1.4*ref*.

Abbreviations, see Clause 1.5*ref*.

Informative references, see Appendix A*ref*.

Introduction to 1000 Mb/s baseband networks, see Clause 34*ref*

Introduction to Ethernet for subscriber access networks, see Clause 56 *ref*.

58.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-PX10 and 1000BASE-PX20 PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation. The PMD Service Interface supports the exchange of 8B/10B code-groups between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium. The following primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indicate

PMD_SIGNAL.request

PMD_SIGNAL.indicate

NOTE1 - Primitives are described in *ref* 1.2.2.

NOTE2 - Delay requirements from the MDI to the GMII which include the PMD layer are specified in clause 36 *ref*. Of the budget, 4 ns is reserved for each of the transmit and receive functions of the PMD

NOTE3 - A signal for laser control is generated in *ref* Clause 64.3.10.2. This signal is used in the upstream direction to give the notice to turn on/off the laser according to the granted time.

58.1.4.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits. The tx_bit parameter can take one of two values: ONE or ZERO. the PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 1250 MBaud signaling speed. Upon receipt of this primative, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

58.1.4.2 PMD_UNITDATA.indicate

This primitive defines the transfer of data from the PMD to the PMA.

The semantics of the service primitive are PMD_UNITDATA.indicate(rx_bit). The data conveyed by PMD_UNITDATA.indicate is a continuous stream of bits. The rx_bit parameter can take one of two values: ONE or ZERO. When generated, the PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

58.1.4.3 PMD_SIGNAL.request

In the upstream direction, this primitive is generated by the MPCP to turn on the transmitter according to the granted time.

The semantics of the service primitive are PMD_SIGNAL.indicate(tx_enable). The tx_enable parameter can take on one of two values: ENABLE or DISABLE, determining whether the PMD transmitter is on (enabled) or off (disabled).The MPCP generates this primitive to indicate a change in the value of tx_enable. Upon receipt of this primitive, the PMD turns the transmitter on or off as appropriate.

58.1.4.4 PMD_SIGNAL.indicate

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indicate(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT =FAIL, PMD_UNITDATA.indicate(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT. If the MDIO interface is implemented, then PMD_global_signal_detect shall be continuously set to the value of SIGNAL_DETECT.

NOTE - SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indicate(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the error rate objective. PMD_SIGNAL.indicate(SIGNAL_DETECT) has different characteristics for upsteam and downstream links, see 58.3.4.

58.2 PMD MDIO function mapping (informative)

The optional MDIO capability described in Clause 45*ref* defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it maps MDIO control variables to PMD control variables as shown in Table 58–2, and MDIO status variables to PMD status variables as shown in Table 58–3.

Table 58–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global transmit disable	Transmit disable register	1.9.0	PMD_global_transmit_disable

Table 58–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD receive signal detect	Receive signal detect register	1.10.0	PMD_global_signal_detect

58.3 PMD functional specifications

The 1000BASE-PX PMDs perform the Transmit and Receive functions that convey data between the PMD service interface and the MDI.

58.3.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 58–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a fibre type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 58.8 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 58.8 are made at TP3.

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-PX PMDs.

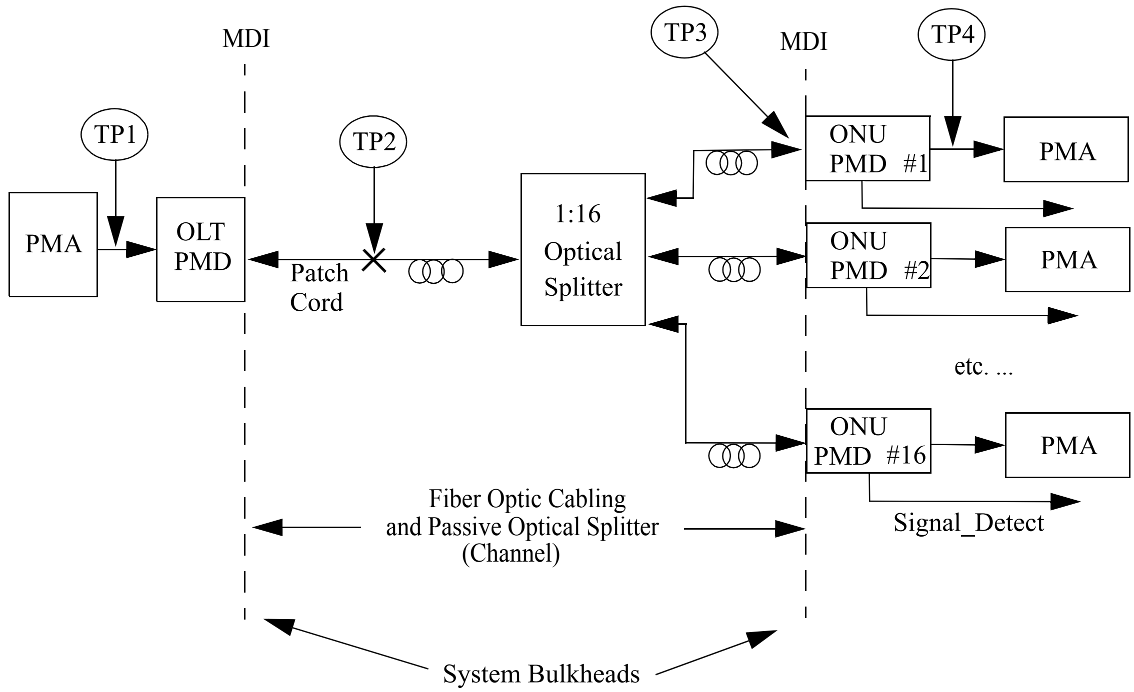

Figure 58–2—1000BASE-PX Block Diagram

58.3.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit =ONE.

In the upstream direction (“U” PMD transmitting), the flow of bits is interrupted according to PMD_SIGNAL.request(tx_enable). This implies three optical levels, 1, 0 and dark, the latter corresponding to the transmitter being in the “OFF” state.

In the upstream direction ("U" PMD transmitting), the flow of bits is interrupted according to PMD_SIGNAL.request(tx_enable). There are three optical levels, 1, 0 and dark.

58.3.3 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indicate(rx_bit). The higher optical power level shall correspond to rx_bit =ONE.

58.3.3.1 OLT

text text text

58.3.3.2 ONU

text text text

58.3.4 PMD signal detect function

58.3.4.1 ONU PMD signal detect (downstream)

The PMD Signal Detect function for the continuous mode downstream signal shall report to the PMD service interface, using the message PMD_SIGNAL.indicate(SIGNAL_DETECT) which is signaled continuously. PMD_SIGNAL.indicate is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 58–5 and Table 58–7 for 1000BASE-PX. The PMD receiver is not required to verify whether a compliant 1000BASE-PX signal is being received.

58.3.4.2 OLT PMD signal detect (upstream)

The response time for the PMD Signal Detect function for the burst mode upstream signal may be longer or shorter than a burst length, thus, it may not fulfil the traditional requirements placed on Signal Detect. PMD_SIGNAL.indicate is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 58–4 and Table 58–6 for 1000BASE-PX. The PMD receiver is not required to verify whether a compliant 1000BASE-PX signal is being received.

58.3.4.3 1000BASE-PX Signal Detect Functions

The Signal Detect value definitions for the 1000BASE-PX PMDs are shown in Table 58–4

58.3.5 PMD transmit enable function for ONU

PMD_SIGNAL.request(tx_enable) is defined for the two ONU PMDs. PMD_SIGNAL.request(tx_enable) is asserted (logic level = 1) prior to data transmition by the ONU PMD.

58.4 PMD to MDI optical specifications for 1000BASE-PX10-D and 1000BASE-PX10-U

The operating range for 1000BASE-PX10 is defined in Table 58–1. A 1000BASE-PX10 compliant transceiver supports all media types listed in Table 58–6 according to the specifications described in 58.10.3. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 10.5 km meets the minimum range requirement of 0.5 m to 10 km for type PX10).

Table 58–4—OLT PX10 SIGNAL_DETECT value definition

Receive conditions		Signal detect value
1000BASE-PX10	**1000BASE-PX20**	
Input optical power ≤ Signal Detect Threshold (min) in Table 58–7 at the specified receiver wavelength	Input optical power ≤ Signal Detect Threshold (min) in Table 58–10 at the specified receiver wavelength	FAIL
Input optical power ≥ Receive sensitivity (max) in Table 58–7 AND compliant 1000BASE-X signal input at the specified receiver wavelength	Input optical power ≥ Receive sensitivity (max) in Table 58–10 AND compliant 1000BASE-X signal input at the specified receiver wavelength	OK
All other conditions	All other conditions	Unspecified

NOTE In this subclause and 58.5, the specifications for OMA have been derived from extinction ratio and average launch power (min) or receiver sensitivity (max). The calculation is explained in 60.8.6*ref*.

58.4.1 1000BASE-PX10 Transmitter optical specifications

The 1000BASE-PX10-D and 1000BASE-PX10-U transmitter shall meet the specifications defined in Table 58–5 per measurement techniques described in 58.8.

Table 58–5—1000BASE-PX10-D and 1000BASE-PX10-U transmit characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Transmitter type	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[a] (range)	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	see Table 58–6		nm
Average launch power (max)	+2	+4	dBm
Average launch power (min)	-3	-1	dBm
Average launch power of OFF transmitter (max)	-39	-45	dBm

Table 58–5—1000BASE-PX10-D and 1000BASE-PX10-U transmit characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Extinction ratio (min)	6	6	dB
RIN_xOMA (max)	tbd	tbd	dB/Hz
Launch OMA (min)	0.6 (-2.2)	0.95 (-0.22)	mW (dBm)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.20, 0.20, 0.30}	tbd	UI
Ton (max)	N.A.	512	ns
Toff (max)	N.A.	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	-12	-12	dB
Transmitter and dispersion penalty (max)			dB

[a]This represents the range of centre wavelength ±1σ of the rms spectral width

***Editors' Note:** To be removed prior to final publication.*
The upstream clock tolerance may need to be widened based on clocking type in PON system

The maximum RMS spectral width vs. wavelength for 1000BASE-PX10 is shown in Table 58–6 and Figure 58–3. The equation used to generate these values is included in 58.8.1. The central column values are normative, the right hand column is informative.

***Editors' Note:** To be removed prior to final publication.*
The epsilon diagrams may be extended in the future to include a third curve representing the spectral requirements of a FEC enabled system

58.4.2 1000BASE-PX10 Receiver optical specifications

The 1000BASE-PX receiver shall meet the specifications defined in Table 58–7 per measurement techniques defined in 58.8. The receive sensitivity includes the extinction ratio penalty.

58.5 PMD to MDI optical specifications for 1000BASE-PX20-D and 1000BASE-PX20-U

The operating range for 1000BASE-PX20 is defined in Table 58–1. A 1000BASE-PX20 compliant transceiver supports all media types listed in Table 58–10 according to the specifications described in 58.10.3. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 20.5 km meets the minimum range requirement of 0.5 m to 20 km for PX20).

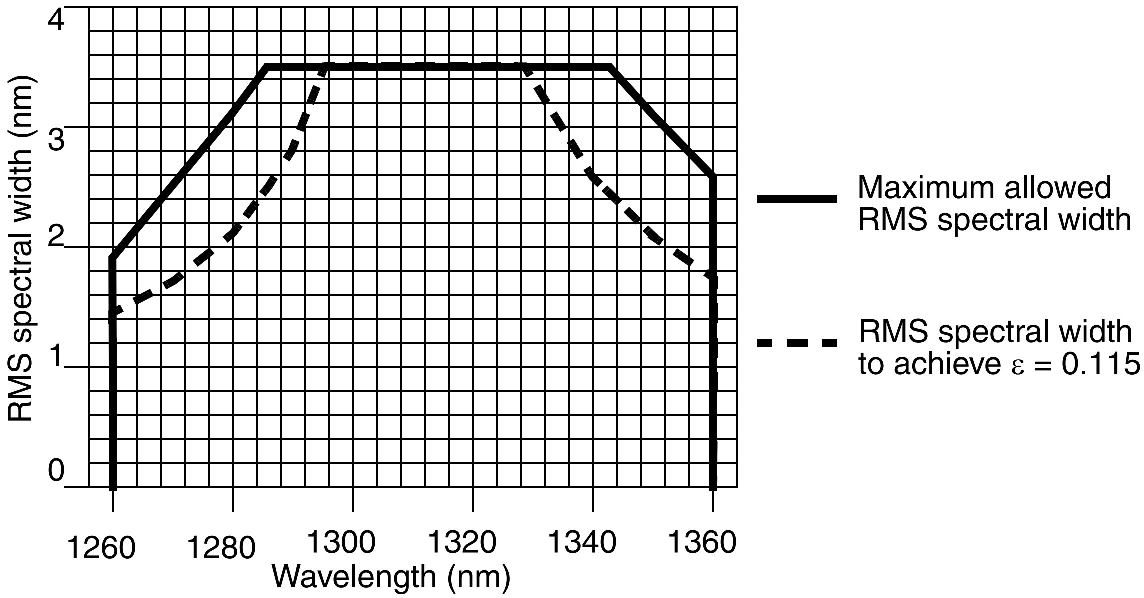

Figure 58–3—1000BASE-PX10-U transmitter spectral limits

Table 58–6—1000BASE-PX10-D and 1000BASE-PX10-U transmitter spectral limits

<table>
<tr><th>Center Wavelength / nm</th><th>RMS spectral width (max)[a] / nm</th><th>RMS spectral width to achieve epsilon ε <=0.115 / nm (informative)</th></tr>
<tr><td>1260</td><td>1.90</td><td>1.43</td></tr>
<tr><td>1270</td><td>2.52</td><td>1.72</td></tr>
<tr><td>1280</td><td>3.13</td><td>2.14</td></tr>
<tr><td>1286</td><td rowspan="7">3.50</td><td>2.49</td></tr>
<tr><td>1290</td><td>2.80</td></tr>
<tr><td>1297</td><td rowspan="2">3.50</td></tr>
<tr><td>1329</td></tr>
<tr><td>1340</td><td>2.59</td></tr>
<tr><td>1343</td><td>2.41</td></tr>
<tr><td>1350</td><td>3.06</td><td>2.09</td></tr>
<tr><td>1360</td><td>2.58</td><td>1.76</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>1480 to 1500</td><td>0.88</td><td>0.60</td></tr>
</table>

[a]These limits for the 1000BASE-PX10-U transmitter are illustrated in Figure 58–3. The equation used to calculate these values is detailed in 58.8.1. Limits at intermediate wavelengths may be found by interpolation

Table 58–7—1000BASE-PX10-D and 1000BASE-PX10-U receive characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Signaling speed (range)	1.25 ± TBD ppm	1.25 ± TBD ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Average receive power (max)	-1	-5	dBm
Damage threshold (max)	+4	+2	dBm
Receiver sensitivity (max)	-24	-24	dBm
Receiver sensitivity OMA (max)	5 (-23.2)	5 (-23.2)	µW (dBm)
Signal Detect Threshold (min)	-44	-45	dBm
Receiver Reflectance (max)	-12	-12	dB
Stressed Receive Sensitivity (max)[a]			dBm
Vertical eye-closure penalty (min)			dB
T_Optical_rec_recovery (max)	400	N.A.	ns
Stressed eye jitter (min)			UI pk to pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)[b]			kHz

[a]The stressed receiver sensitivity recommendation is informative, not mandatory
[b]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

NOTE In this subclause and 58.4, the specifications for OMA have been derived from extinction ratio and average launch power (min) or receiver sensitivity (max). The calculation is explained in 60.8.6*ref*.

58.5.1 1000BASE-PX20 Transmit optical specifications

The 1000BASE-PX20-D and 1000BASE-PX20-U transmitter shall meet the specifications defined in Table 58–8 per measurement techniques described in 58.8.

Table 58–8—1000BASE-PX20-D and 1000BASE-PX20-U transmit characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Transmitter type	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[a] (range)	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	see Table 58–9		nm
Average launch power (max)	+7	+4	dBm
Average launch power (min)	+2	-1	dBm
Average launch power of OFF transmitter (max)	-39	-45	dBm
Extinction ratio (min)	6	6	dB
RIN_xOMA (max)	tbd	tbd	dB/Hz
Launch OMA (min)	1.9 (2.8)	0.95 (-0.22)	mW (dBm)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.20, 0.20, 0.30}	tbd	UI
Ton (max)	N.A.	512	ns
Toff (max)	N.A.	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	-12	-12	dB
Transmitter and dispersion penalty (max)			dB

[a]This represents the range of centre wavelength ±1σ of the rms spectral width

***Editors' Note:** To be removed prior to final publication.*
The upstream clock tolerance may need to be widened based on clocking type in PON system

The maximum RMS spectral width vs. wavelength for 1000BASE-PX20 is shown in Table 58–9 and Figure 58–4. The equation used to generate these values is included in 58.8.1. The central column values are normative, the right hand column is informative.

> ***Editors' Note:*** *To be removed prior to final publication.*
> *The limits for the rms values have been revisited to reflect the penalty allocations of Table 58–11. The reduced value of epsilon (compared to 1000BASE-PX-10 links) ensures a link penalty less than 2 dB at 20 km*

Table 58–9—1000BASE-PX20-D and 1000BASE-PX20-U transmitter spectral limits

Center Wavelength / nm	RMS spectral width (max) [a]/ nm	RMS spectral width to achieve epsilon ε <=0.115 / nm (informative)
1260	**0.72**	0.62
1270	**0.86**	0.75
1280	**1.07**	0.93
1290	**1.40**	1.22
1300	**2.00**	1.74
1304	**2.42**	2.5
1305	**2.55**	2.5
1308	**3.00**	
1317		
1320	**2.53**	2.2
1321	**2.41**	
1330	**1.71**	1.48
1340	**1.29**	1.12
1350	**1.05**	0.91
1360	**0.88**	0.77
1480 to 1500	**0.44**	0.30

[a]These limits for the 1000BASE-PX20-U are illustrated in Figure 58–4. The equation used to calculate these values is detailed in 58.8.1. Limits at intermediate wavelengths may be found by interpolation

58.5.2 1000BASE-PX20 Receiver optical specifications

The 1000BASE-PX receiver shall meet the specifications defined in Table 58–10 per measurement techniques defined in 58.8. The receive sensitivity includes the extinction ratio penalty.

58.6 Illustrative 1000BASE-PX10 and 1000BASE-PX20 link power budgets (informative)

Illustrative power budget for 1000BASE-PX10 and 1000BASE-PX20 channels are shown in Table 58–14.

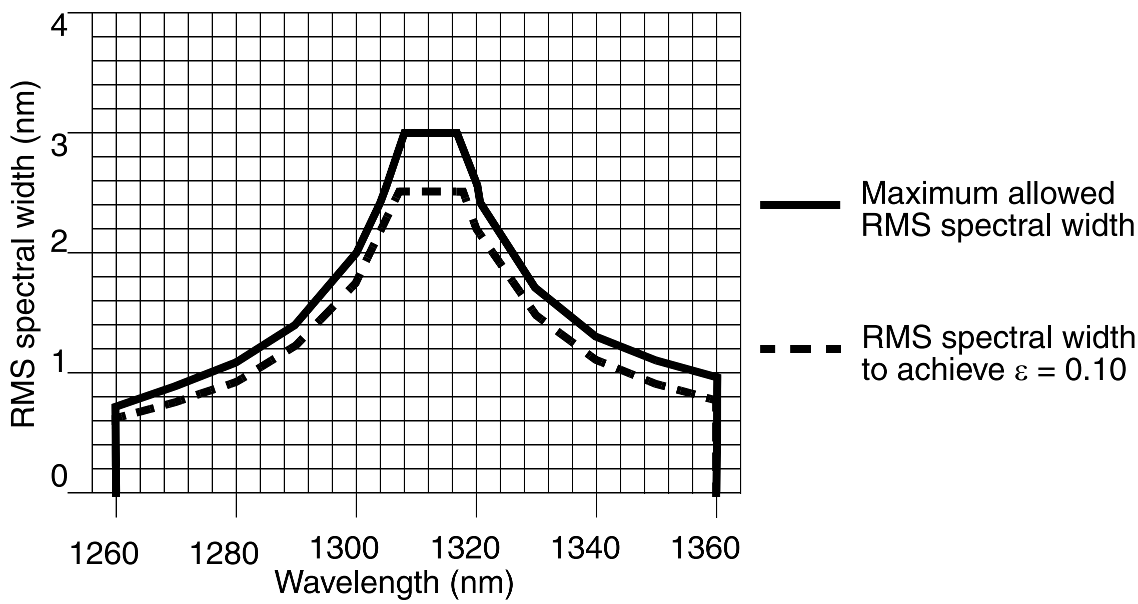

Figure 58–4—1000BASE-PX20-U transmitter spectral limits

Table 58–10—1000BASE-PX20-D and 1000BASE-PX20-U receive characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Average receive power (max)	-6	-3	dBm
Damage threshold (max)	+4	+7	dBm

Table 58–10—1000BASE-PX20-D and 1000BASE-PX20-U receive characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Receive Sensitivity (max)	-27	-24	dBm
Receiver sensitivity OMA (max)	2.0 (-26.2)	5 (-23.2)	µW (dBm)
Signal Detect Threshold (min)	-44	-45	dBm
Receiver Reflectance (max)	-12	-12	dB
Stressed Receive Sensitivity (max)[a]			dBm
Vertical eye-closure penalty (min)			dB
T_Optical_rec_recovery (max)	400	N.A.	ns
Stressed eye jitter (min)			UI pk to pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)[b]			kHz

[a]The stressed receiver sensitivity recommendation is informative, not mandatory
[b]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

Table 58–11—Illustrative 1000BASE-PX10 and 1000BASE-PX20 channel insertion loss and penalties

Description	1000BASE-PX10		1000BASE-PX20		Units
	Upstream	Downstream	Upstream	Downstream	
Fibre Type	B1.1, B1.3 SMF				
Measurement wavelength for fibre	1310	1550	1310	1550	nm
Nominal Distance	10		20		km
Available Power Budget	23.0	21.0	26.0	26.0	dB
Channel insertion loss(max)[a]	20	19.5	24	23.5	dB
Channel insertion loss (min)[b]	5		10		dB
Allocation for penalties[c]	3	1.5	2	2.5	dB
Optical return loss of ODN (min)	20				dB

[a]The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components such as splitters
[b]The power budgets for PX10 and PX20 links are such that a minimum insertion loss is assumed between transmitter and receiver. This mimimum attenuation is required for PMD testing

[c]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in 58.8.1.

58.7 Jitter at TP1-4 for 1000BASE-PX10 and 1000BASE-PX20 (informative)

The entries in Table 58–12 and Table 58–13 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. They are two sided (peak-to-peak) measures. Table 58–12 applies to the downstream direction (D to U) while Table 58–13 applies to the upstream direction (U to D). All values are informative.

Table 58–12—1000BASE-PX10 and 1000BASE-PX20 downstream jitter budget (informative)

	Total jitter		Deterministic jitter	
Reference Point	**UI**	**ps**	**UI**	**ps**
TP1	0.240	192	0.100	80
TP1 to TP2				
TP2				
TP2 to TP3				
TP3	0.510	408	0.250	200
TP3 to TP4				
TP4	0.749	599	0.462	370

Table 58–13—1000BASE-PX10 and 1000BASE-PX20 upstream jitter budget (informative)

	Total jitter		Deterministic jitter	
Reference Point	**UI**	**ps**	**UI**	**ps**
TP1				
TP1 to TP2				
TP2				
TP2 to TP3				
TP3				
TP3 to TP4				
TP4				

58.8 Optical measurement requirements

All optical measurements except, TDP and RIN_xOMA, shall be made through a short patch cable, between 2 and 5 m in length.

> ***Editors' Note:*** *To be removed prior to final publication.*
> *non-FEC links are tested to a BER of 10^{-12}, links with FEC are tested to a BER of 10^{-4}*

58.8.1 Frame based test patterns

The frame based test patterns defined here are suitable for testing all Clause 58 and 59*ref* PMDs. The test suite and the recommended patterns are shown below.

Table 58–14—List of test patterns and tests

Test Pattern	Tests
Any valid 8B/10B encoded signal	Eye Mask Optical Power Extinction Ratio OMA Central Wavelength Spectral Width
Random Pattern Test Frame	Receiver Sensitivity Stressed Receiver Sensitivity Receiver 3dB Upper Cutoff Frequency TDP
Jitter Pattern Test Frame	All Jitter Tests
Test Pattern not Frame Based	RIN_xOMA

58.8.1.1 Frame Based Test Patterns

The following test patterns are intended for frame based testing of the 1000BASE-X PMDs of Clauses 58 and 59. They are compliant Ethernet frames with adequate user defined fields to allow them to be routed through a system to the point of the test. The common portions of the frames are given in Table 58–15.

Two payloads are defined. the first is a random pattern broad spectral content and minimal peaking shown in Table 58–16. This pattern may be used for general testing.

The payload for the second pattern is shown in Table 58–17. This pattern has areas of high and low density to aggravate jitter susceptibility.

> ***Editors' Note:*** *To be removed prior to final publication.*
> *The above section of Frame based testing results from comment 1007 made against D1.3 and is for further study*

Table 58–15—Common Portion of Frame Based Test Pattern

Field	Number of Octets	Hexadecimal
Idle	7	55
SOF	1	D5
Destination Address	6	User Defined
Source Address	6	User Defined
Length / Type	2	User Defined
First Portion of MAC Client Data	32	User Defined
Second Portion of MAC Client Data	228	See Table 58–16 or Table 58–17
Frame Check Sequence	4	As required by frame

Table 58–16—Payload for Random Pattern Test Frame

Field	Number of octets	Hexadecimal
Second Portion of MAC Client Data	228	The 12 Octet field "BE D7 23 47 6B 8F B3 14 5E FB 35 59" repeated 19 times

Table 58–17—Payload for Jitter Pattern Test Frame

Field	Number of Octets	Hexadecimal
Low transition density	164	7E repeated 164 times
Transition from Low to High Density pattern	8	7E 7E 7E 74 7E AB B5 B5
High Transition Density	48	B5 repeated 48 times
Transition from High to Low Density Pattern	8	B5 5E A4 7E 7E 7E 7E 7E

58.8.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall be assured in relation to measurement procedures using an optical spectrum analyzer per ANSI/EIA/TIA-455-127, under modulated conditions using a valid 1000BASE-X signal.

NOTE1: The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme

NOTE2: The 20 dB width for SLM lasers is taken as 6.07 times the RMS width.

The interaction between the transmitter and the chromatic dispersion of the fiber is accounted for by a parameter ε (epsilon), which is defined as the product of 10^{-3} times the signaling speed (in GBd) times the path dispersion (in ps/nm) times the RMS spectral width (in nm).

$$\varepsilon = \text{dispersion} \cdot \text{length} \cdot \text{RMS spectral width} \cdot \text{signaling speed} \qquad (58\text{-}1)$$

A maximum ε close to 0.168 is imposed by the middle column of Table 58–6 and Table 58–9. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.115, and the chromatic dispersion penalty is expected to be below 2 dB when all link parameters are simultaneously at worst case values. The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP) which is specified in Table 58–5, Table 58–8 and described in 60.7.9 *ref*.

58.8.3 Optical power measurements

Optical power shall be measured using the methods specified in ANSI/EIA-455-95 [B7]. This measurement may be made with the node transmitting any valid encoded 8B/10B data stream.

58.8.4 Extinction ratio measurements

Extinction ratio is defined according to the methods specified in ANSI/TIA/EIA-526-4A with the node transmitting a repeating idle pattern I2 and with minimal back reflections into the transmitter, lower than -20 dB. This is defined in Clause 36*ref*, and is coded as /K28.5/D16.2/ which is binary 001111 1010 100100 0101 or 110000 0101 011011 0101.

58.8.5 OMA measurements (informative)

ref Clause 60.8.5 provides a reference technique for performing OMA measurements.

58.8.6 OMA relationship to Extinction Ratio and Power Measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. *ref* Clause 60.8.6 provides a reference to the reader. That clause is intended to inform on how the three quantaties OMA, extinction ratio, and mean power, are related to each other.

58.8.7 Relative intensity noise optical modulation amplitude (RIN_xOMA)

RIN_xOMA is the ratio of noise to modulated optical signal in the presence of a back reflection. The measurement procedure is described in *ref* 60.8.7.

58.8.8 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 58–5.

Normalized amplitudes of 0.0 and 1.0 represent the amplitudes of the logic ZERO and ONE respectively.

The eye shall be meaured with repect to the mask of the eye using a fourth-order Bessel Thomson filter have the transfer function given by:

$$H(p) = \frac{105}{105 + 105y + 45y^2 + 10y^3 + y^4} \qquad 58\text{-}2$$

where,

$$y = 2.114p \; ; \quad p = \frac{j\omega}{\omega_r} \; ; \quad \omega_r = 2\pi f_r \; ; \quad f_r = 0.9375 GHz$$

and where the filter response vs. frequency range for this fourth order Bessel Thomson filter is defined in ITU-T G.957, along with the allowed tolerances for its physical implementation.

NOTE 1- This Bessel Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions on the transmitter.

NOTE 2 - The fourth order Bessel Thomson filter is reactive. In order to surpress reflections, a 6 dB attenuator may be required at the filter input and/or output.

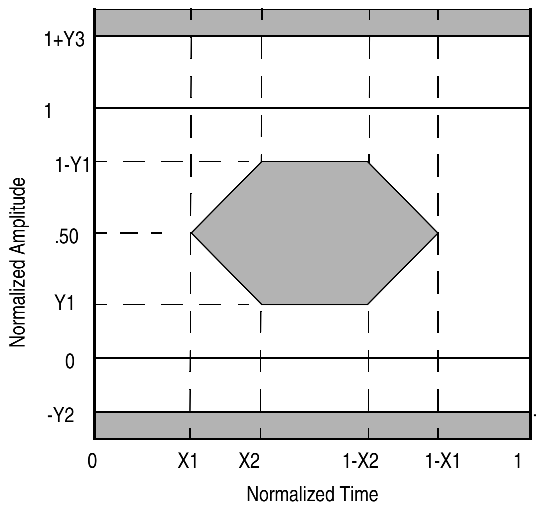

Figure 58–5—Transmitter eye mask definition

> ***Editors' Note:*** *To be removed prior to final publication.*
> *NOTE: There has been no agreement on the eyemask for upstream PON transmitters.*

58.8.9 Transmitter and dispersion penalty

The transmitter and dispersion penalty (TDP) measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single mode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g. eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The TDP limit shall be met. See *ref*60.8.9 for details of the measurement.

58.8.10 Receive sensitivity measurement

The receive sensitivity shall be measured using a worst-case extinction ratio penalty while sampling at the eye center.

The stressed receive sensitivity shall be measured using the conformance test signal at TP3, as specified in *ref* 59.8.13. After correcting for the extinction ratio of the source, the stressed receive sensitivity shall meet the conditions specified in Table 58–7 for 1000BASE-PX10 and in Table 58–10 for 1000BASE-PX20.

58.8.11 Stressed receive conformance test (informative)

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. The conformance test signal is conditioned by applying deterministic jitter and intersymbol interference. Receiver sensitivity is assured in relation to the measurement procedures of 60.8.11 *ref* and the specifications of the appropriate receiver Table 58–7 and Table 58–10, using the short continuous random test pattern defined in *ref* 36A.5.

58.8.12 Jitter measurements (informative)

Jitter measurements for 1000 Mbps are described in *ref* 60.8.12

58.8.13 OTHER MEASUREMENTS

58.8.13.1 Transmitter switch-on/off time

58.8.13.1.1 Definitions

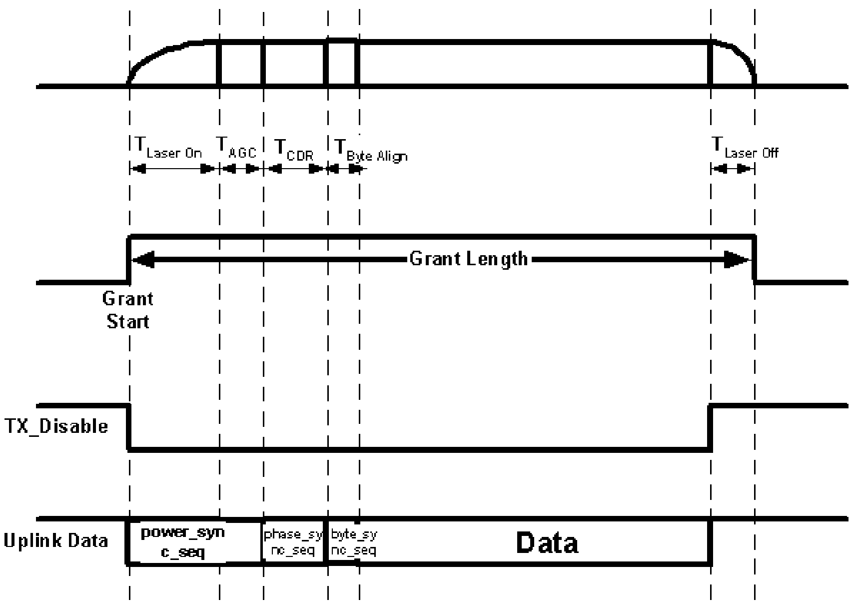

Figure 58–6—EPON timing parameter definition

Denote T_{laser_on} as the time from the falling edge of the TX_disable line to the time that the optical signal at TP2 reaches (90%, or with in ±1dB) of its Average launch power, its specified average optical wavelength, its specified RMS spectral width, its specified dispersion penalty, its specified return loss tolerance, its specified jitter, its specified RIN_xOMA, its specified CPR, its specified extinction ratio, and its specified opening of the eye diagram, as presented in Figure 58–5. The data transmitted may be any valid 8B/10B symbols.

Standard defines maximal values.

Denote T_{laser_off} as the time from the rising edge of the TX_disable line to the time that the optical signal at TP2 reaches (10%, or with in ±1dB) above its Average launch power of off transmitter, as presented in Figure 58-5. The data transmitted may be any valid 8B/10B symbols.

Standard defines maximal values

58.8.13.2 AGC lock and CDR lock timing measurement

58.8.13.2.1 Definition

Denote T_{AGC_lock} as the time from the time that the optical power in the receiver at TP3 reaches the conditions specified in 58.8.13.1.1 to the time that the electrical signal after the PMD at TP4, reaches (90%, or with in ±1 dB) of its Average steady state power, its specified jitter and its specified opening of the eye diagram at the receiver, as presented in Figure 58–5. The data transmitted may be any valid 8B/10B symbols (or a specific preamble). Also optical signal at TP3, at the beginning of the locking, may have any Rx power level or frequency shift matching the standard specifications.

Standard defines maximal values.

Denote T_{CDR_lock} as the time from the time that the electrical signal after the PMD at TP4, the conditions specified in the section above to, the time the CDR acquires the phase and frequency of the electrical signal (Phase reaching up to tbd° difference degrading up to 1 dB according to the eye diagram in figure 38-2), as presented in Figure 58–5. The data transmitted may be any valid 8B/10B symbols (or a specific preamble).

Standard defines maximal values.

58.9 Environmental, safety and labeling

58.9.1 General Safety

All equipment meeting this standard shall conform to IEC 60950

58.9.2 Laser Safety

1000BASE-PX10 and 1000BASE-PX20 optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825-1, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

58.9.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

58.9.4 Environment

Reference *ref* Annex 66A for additional environmental information.

58.9.5 PMD labelling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 1000BASE-PX10-U).

Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 58.9.2.

Each systems and field pluggable component shall be clearly labeled with its operating temperature range over which their compliance is ensured.

58.10 Characteristics of the fiber optic cabling

58.10.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 58–7

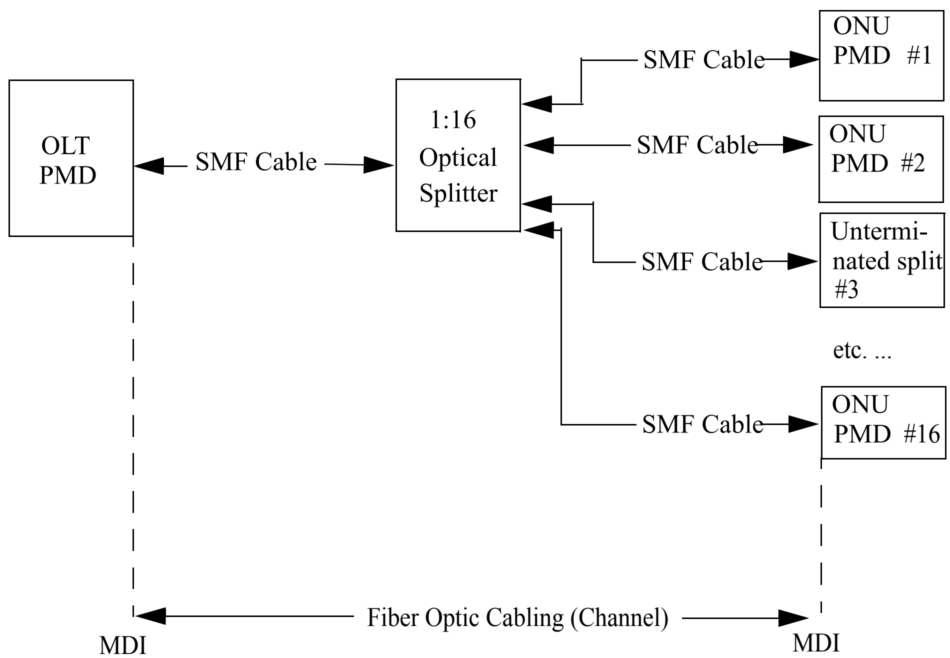

Figure 58–7—Fiber Optic Cable Model

NOTE: The 1:16 optical splitter may be replaced by a number of smaller 1:n splitters such that a different topology may be implemented while preserving the link characteristics and power budget as defined in Table 58–11.

The maximum channel insertion losses shall meet the requirements specified in Table 58–1. Insertion loss measurements of installed fiber cables are made in accordance with and ANSI/TIA/EIA-526-7 [B15], method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

58.10.2 Optical fiber and cable

The 1000BASE-PX fiber optic cabling shall meet the dispersion specifications defined in IEC 60793-2 and ITU G.652, as shown in Table 58–18. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. It also includes a connector plug at each end to connect to the MDI. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 58–7.

58.10.3 Optical fiber connection

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2:1992. Type B1.1 (dispersion un-shifted single mode) and B1.3 (low water peak single mode) as in Table 58–17.

Table 58–18—Optical fiber cable characteristics

Description[a]	Type B1.1, B1.3 SMF		Unit
Nominal wavelength[b]	1310	1550	nm
Cable attenuation (max)[c]	0.4	0.35	dB/km
Zero dispersion wavelength[d]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max)	0.093		ps / nm^2 · km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Wavelength specified is the nominal wavelength and typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation for single-mode optical fiber cables is defined in ITU-T G.652.
[d]See IEC 60793 or G.652

An optical fiber connection as shown in Figure 58–7 consists of a mated pair of optical connectors. The 1000BASE-PX is coupled to the fiber optic cabling through an optical connection and any optical splitters into the MDI optical receiver, as shown in Figure 58–7. The channel insertion loss includes the loss for connectors, splices and other passive components such as splitters, see Table 58–11

The link attenuations have been calculated on the assumption of 14.5 dB for a 16:1 splitter; 3.5, 4, 7.5 or 8 dB (at the appropriate measurement wavelength) for fibre cable attenuation and 1.5 dB for connectors and splices. For example, this allocation supports three connections with an average insertion loss equal to 0.5 dB (or less) per connection, or two connections with a maximum insertion loss of 0.75 dB. Other arrangements, such as a shorter link length and a higher split ratio in the case of 1000BASE-PX20, may be used provided the requirements of Table 58–1 are met.

The maximum discrete reflectance for single-mode connections shall be less than -26 dB.

58.10.4 Medium Dependent Interface (MDI)

The 1000BASE-PX10 or 1000BASE-PX20 PMDs are coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" as shown in Figure 58–7. Examples of an MDI include:

(a) Connectorized fiber pigtail

(b) PMD receptacle

When the MDI is a remateable connection, it shall meet the interface performance specifications of IEC 61753-1-1, Fibre optic interconnecting devices and passive component performance standard - Part 1-1:General and guidance interconnecting devices (connectors).

NOTE: Compliance testing is performed at TP2 and TP3, not at the MDI.

58.11 Protocol Implementation Conformance Statement (PICS) proforma for Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10 and 1000BASE-PX20 (long wavelength passive optical networks)

58.11.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX, shall complete the following Protocol Implementation Conformance Statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21 *ref*.

58.11.2 Identification

58.11.2.1 Implementation identification

Supplier[1]	
Contact point for enquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTES 1—Required for all implementations. 2—May be completed as appropriate in meeting the requirements for the identification. 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

58.11.2.2 Protocol Summary

Identification of protocol standard	IEEE Std 802.3ah-2003, Clause 58*ref*, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASEPX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21*ref*; the answer Yes means that the implementation does not conform to IEEE Std 802.3ah-2003.)	

Date of Statement	

58.11.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*MD	MDIO capability	58.2	Registers and interface supported.	O	Yes [ ] No [ ]
*HT	High temperature operation	58.1	XX to YY °C	O	Yes [ ] No [ ]
*LT	Low temperature operation	58.1	WW to ZZ °C	O	Yes [ ] No [ ]
*PX10U	1000BASE-PX10-D or 1000BASE-PX10-U PMD	58.3	Device supports 10km	O/1	Yes [ ] No [ ]
*PX10D	1000BASE-PX10-D or 1000BASE-PX10-U PMD	58.3	Device supports 10km	O/1	Yes [ ] No [ ]
*PX20U	1000BASE-PX20-D or 1000BASE-PX20-U PMD	58.4	Device supports 20km	O/1	Yes [ ] No [ ]
*PX20D	1000BASE-PX20-D or 1000BASE-PX20-U PMD	58.4	Device supports 20km	O/1	Yes [ ] No [ ]
*INS	Installation / Cable	58.4.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]

Editors' Note: *To be removed prior to final publication.*
The temperature limit values of XX, YY, WW and ZZ in the above table are for discussion in the STF

58.11.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-PX10-D (PON OLT PX10), 1000BASE-PX10-U (PON ONU PX10), 1000BASE-PX20-D (PON OLT PX20) and 1000BASE-PX20-U (PON ONU PX20)

58.11.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Transmit function	58.3.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FS2	Transmitter optical signal	58.3.2	Higher optical power transmitted is a logic 1	M	Yes [ ]
FS3	Receive function	58.3.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FS4	Receiver optical signal	58.3.3	Higher optical power received is a logic 1	M	Yes [ ]
FS5	Signal detect function (downstream)	58.3.4.1	Mapping to PMD service interface	M	Yes [ ]
FS6	Signal detect parameter (downstream)	58.3.4.1	Generated according to Table 58–4	M	Yes [ ]
FS8	Signal detect parameter (upstream)	58.3.4.2	Generated according to Table 58–4	M	Yes [ ]

58.11.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support

58.11.4.3 PMD to MDI optical specifications for 1000BASE-PX10

Item	Feature	Subclause	Value/Comment	Status	Support
PX10: TX	1000BASE-PX10-D 1000BASE-PX10-U Transmit	58.4.1	Meets specifications in Table 58–5	PX10:M	Yes [ ] N/A [ ]
PX10: SW	1000BASE-PX10-D and 1000BASE-PX10-U RMS spectral width	58.4.1	Meets specifications in Figure 58–3 and Table 58–6	PX10:M	Yes [ ] N/A [ ]
PX10: RX	1000BASE-PX10-D 1000BASE-PX10-U Receive	58.4.2	Meets specifications in Table 58–7	PX10:M	Yes [ ] N/A [ ]

58.11.4.4 PMD to MDI optical specifications for 1000BASE-PX20

Item	Feature	Subclause	Value/Comment	Status	Support
PX20: TX	1000BASE-PX20-D and 1000BASE-PX20-U Transmit	58.5.1	Meets specifications in Table 58–8	PX20:M	Yes [ ] N/A [ ]
PX20: EYE	1000BASE-PX20-D and 1000BASE-PX20-U TX Eye	58.5.1	Meets specifications in 58.8.8 and Figure 58–5	PX20:M	Yes [ ] N/A [ ]
PX20: SW	1000BASE-PX20-D and 1000BASE-PX20-U RMS spectral width	58.5.1	Meets specifications in Figure 58–4 and Figure 58–9	PX20:M	Yes [ ] N/A [ ]
PX20: RX	1000BASE-PX20-D and 1000BASE-PX20-U Receive	58.5.2	Meets specifications in Figure 58–10	PX20:M	Yes [ ] N/A [ ]

58.11.4.5 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	58.8	2 to 5 meters in length	M	Yes [ ]
OM2	Wavelength and spectral width measurement	58.8.2	Measured using an optical spectrum analyzer per TIA/EIA-455-127 under modulated conditions	M	Yes [ ]
OM3	Average optical power	58.8.3	Measured using the methods specified in TIA/EIA-455-95[B7]	M	Yes [ ]
OM4	Extinction ratio	58.8.4	Measured using the methods specified in ANSI/TIA/EIA-526-4A-1997 [B13]	M	Yes [ ]
OM5	OMA measurement bandwidth	58.8.6	As described in 60.7.6 *ref*	M	Yes [ ]
OM6	RIN_xOMX	58.8.7	As described in 60.8.7 *ref*	M	Yes [ ]
OM7	Transmit eye	58.8.8	Eye must be measured with respect to mask and using Bessel Thomson filter	M	Yes [ ]
OM8	Transmitter and dispersion penalty measurements	58.8.9	As described in 60.8.9 *ref*	M	Yes [ ]

58.11.4.6 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	58.10	Specified in Table 58–18	INS:M	Yes [ ]
FO4	Maximum discrete reflectance - singlemode fiber	58.10.2	Less than -26 dB	INS:M	Yes [ ] N/A [ ]

58.11.4.7 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	58.9.1	Conforms to IEC-60950	M	Yes [ ]
ES2	Laser safety —IEC Class 1	58.9.2	Conform to Class 1 laser requirements defined in IEC 60825-1	M	Yes [ ]
ES3	Documentation	58.9.2	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labelling	58.9.5		M	Yes [ ]

59. Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 (Long Wavelength) and 1000BASE-BX10 (BiDirectional Long Wavelength)

Editors' Notes: To be removed prior to final publication.

1. 1*000Base-EX MMF information is a placeholder until further data is presented or decsision to remove is mad*e
3. Remove references to dates on ANSI standards. Send note to CLAUSE 1
5. *ref* is intended to highlight references outside of this clause that will be adjusted prior to publication
6. Table 59–6 may be replaced by a set of curves at final publication
7. Prior to publication, task force to decide on keeping the 3dB electrical cuttoff frequency measurement or replacing with a refererence to C38, keeping the optical fiber and cable clause or replacing with a refererence to C38, and keeping the offset launch mode conditioning patchcord text or replacing with a refererence to C38
9. Clause 59.1.1, Goals and Objectives to be removed prior to publication.

References:

Add ANSI/EIA/TIA-455-127, currently [B8] of annex A, to the normative reference list.

Definitions (to be added to 1.4):

Coupled Power Ratio (CPR): The ratio (in dB) of the total power coupled into a multimode fiber to the optical power that can be coupled into a single-mode fiber

Abbreviations (to be added to 1.5):

None.

Revision Hisory:

Draft 0.9	June 2002	Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.0	August 2002	Draft 1.0 for IEEE P802.3ah Task Force review.
Draft 1.1	October 2002	Draft 1.1 for IEEE P802.3ah Task Force review.
Draft 1.2	November 2002	Draft 1.2 for IEEE P802.3ah Task Force review.
Draft 1.3	January 2003	Draft 1.3 for IEEE P802.3ah Task Force review.
Draft 1.414	April 2003	Draft 1.3 for IEEE P802.3ah Task Force review.

59.1 Overview

The 1000BASE-LX10 and 1000BASE-BX10 PMD sublayers provide point-to-point 1000 Mb/s Ethernet connections over pairs or individual fibers respectively, up to 10 km long.

This clause specifies the 1000BASE-LX10 PMD for both single-mode and multi-mode fiber, and the 1000BASE-BX10 PMD and baseband medium for single-mode fiber. The Media Dependent Interface (MDI) is described. In order to form a complete Physical Layer, a PMD shall be integrated with the 1000BASE-X PCS and PMA of Clause 36 *ref* and optionally integrated with the management functions which may be accessible through the Management Interface defined in Clause 22 *ref* or Clause 45 *ref*, which are hereby incorporated by reference

Table 59-1 shows the primary attributes of each PMD type.

Table 59–1—Classification of 1000BASE-LX10 and 1000BASE-BX10 PMDs

Description	1000BASE-LX10		1000BASE-BX10-U	1000BASE-BX10-D
Fiber type	B1.1, B1.3 SMF	50, 62.5 µm MMF	B1.1, B1.3 SMF	
Number of fibers	2	2	1	1
Typical transmit direction	N/A	N/A	Upstream	Downstream
Nominal transmit wavelength	1310nm	1310nm	1310nm	1490nm
Minimum range	0.5m to 10km	0.5m to 550m[a]	0.5m to 10km	0.5m to 10km
Maximum channel insertion loss[b]	6.0dB	2.4dB	6.0dB	5.5dB

[a]see Table 59–18 for fiber and cable characteristics
[b]at the nominal operating wavelength

A 1000BASE-LX10 link uses 1000BASE-LX10 PMDs at each end while a 1000BASE-BX10 link uses a 1000BASE-BX10-U PMD at one end and a 1000BASE-BX10-D PMD at the other. Typically the 1550 nm band is used to transmit away from the center of the network (“downstream”) and the 1310 nm band towards the center (“upstream”), although this arrangement, or the notion of hierarchy, is not required. The suffixes “D” and “U” indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions.

Two optional temperature ranges are defined; see Annex 66A*ref* for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

59.1.1 Goals and Objectives

Support subscriber access network topologies:

Point to point on optical fiber

Such that:

Provide a family of physical layer specifications:

1000BASE-LX extended temperature range optics

1000BASE-X >= 10km over SM fiber

PHYs to have a BER better than or equal to10^-12 at the PHY service interface

59.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 59–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

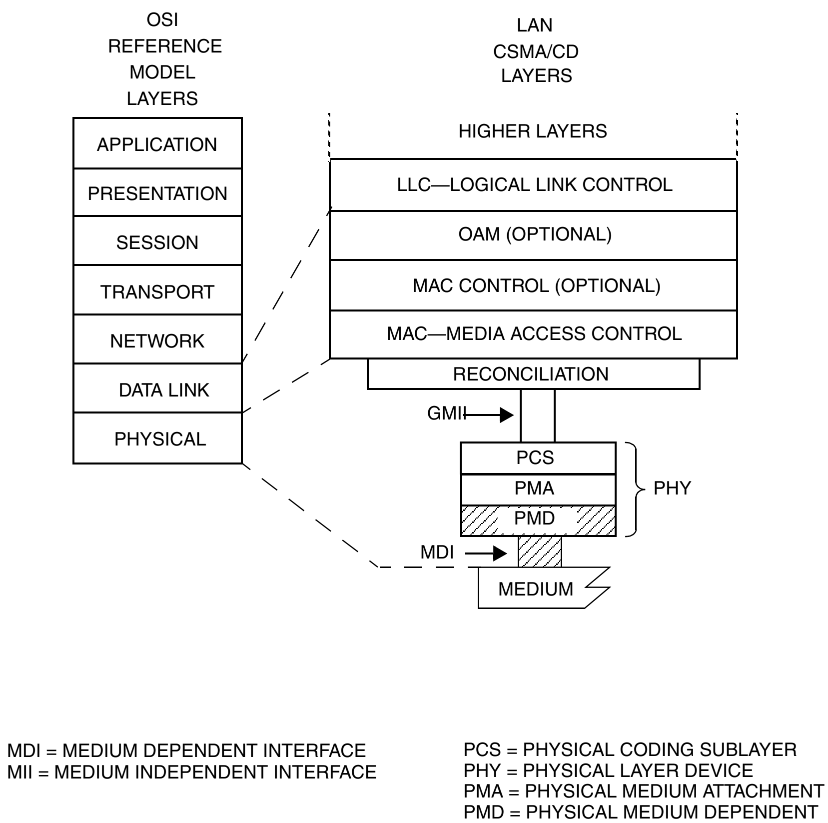

Figure 59–1—1000BASE-LX10 and 1000BASE-BX10 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

59.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

Basic terminology and conventions, see Clause 1.1*ref* and Clause 1.2*ref*.

Normative references, see Clause 1.3*ref*.

Definitions, see Clause 1.4*ref*.

Abbreviations, see Clause 1.5*ref*.

Informative references, see Appendix A*ref*.

Introduction to 1000 Mb/s baseband networks, see Clause 34*ref*.

59.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-LX10 and 1000BASE-BX10 PMDs. These PMD sublayers are described in an abstract manner and do not imply any particular implementation. The PMD service interface supports the exchange of encoded 8B/10B code-groups between the PMA and PMD entities. The PMD translates the the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined

PMD_UNITDATA.request

PMD_UNITDATA.indicate

PMD_SIGNAL.indicate

NOTE 1 - Primitives are described in 1.2.2 *ref*

NOTE 2- Delay requirements from the MDI to the GMII which include the PMD layer are specified in clause 36 *ref*. Of the budget, 4 ns is reserved for each of the transmit and receive functions of the PMD.

59.1.4.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits where the tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 1.25 GBaud signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

59.1.4.2 PMD_UNITDATA.indicate

This primitive defines the transfer of data from the PMD to the PMA.

The semantics of the service primitive are PMD_UNITDATA.indicate(rx_bit). The data conveyed by PMD_UNITDATA.indicate is a continuous stream of bits where the rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

59.1.4.3 PMD_SIGNAL.indicate

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indicate(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indicate(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indicate(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the error rate objective.

59.2 PMD MDIO function mapping (informative)

The optional MDIO capability described in Clause 45*ref* defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it maps MDIO control variables to PMD control variables as shown in Table 59–2, and MDIO status variables to PMD status variables as shown in Table 59–3.

Table 59–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global transmit disable	Transmit disable register	1.9.0	PMD_global_transmit_disable

Table 59–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD receive signal detect	Receive signal detect register	1.10.0	PMD_global_signal_detect

59.3 PMD functional specifications

The 1000BASE-X PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

59.3.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Table 59–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implemnters. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the end of this single-mode fiber offset-launch mode-conditioning patch cord at TP2. Unless specified otherwise, all transmitter measurements and tests defined in 59.9 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 59.9 are made at TP3.

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-X PMD types.

59.3.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit =ONE.

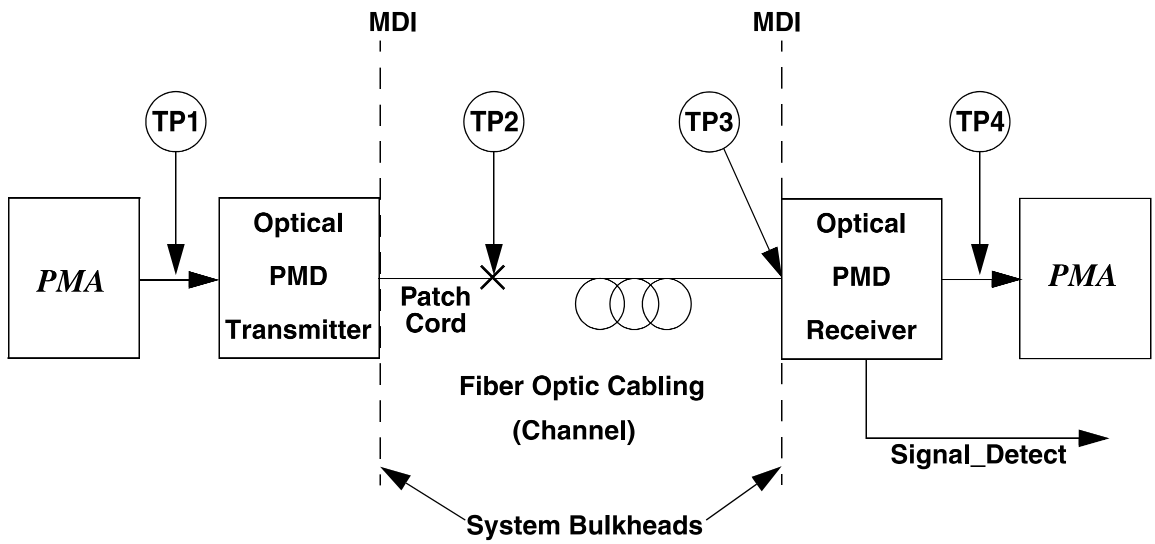

Figure 59–2—1000BASE-X block diagram

59.3.3 PMD receive function

The PMD receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indicate(rx_bit). The higher optical power level shall correspond to rx_bit =ONE.

59.3.4 PMD signal detect function

The PMD signal detect function shall report to the PMD service interface using the message PMD_SIGNAL.indicate(SIGNAL DETECT) which is signaled continuously. PMD_SIGNAL.indicate is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 59–4. The PMD receiver is not required to verify whether a compliant 1000BASE-X signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the Signal Detect function are permitted by this standard, including implementations which generate the SIGNAL_DETECT parameter values in response to the amplitude of the 8B/10B modulation of the optical signal and implementations which respond to the average optical power of the 8B/10B-modulated optical signal.

Table 59–4—1000BASE-LX10 and 1000BASE-BX10 SIGNAL_DETECT value definition

Receive conditions		Signal detect value
1000BASE-LX10	**1000BASE-BX10**	
Input optical power ≤ signal detect threshold (min) in Table 59–7	Input optical power ≤ signal detect threshold (min) in Table 59–9	FAIL
Input optical power ≥ receiver sensitivity (max) in Table 59–7 AND compliant 1000BASE-LX or 1000BASE-LX10 signal input	Input optical power ≥ receiver sensitivity (max) in Table 59–9 AND compliant 1000BASE-BX10 signal input at the specified receiver wavelength	OK
All other conditions		Unspecified

59.4 PMD to MDI optical specifications for 1000BASE-LX10

The operating range for 1000BASE-LX10 is defined in Table 59–1. A 1000BASE-LX10 compliant transceiver operates over the media types listed in Table 59–1 according to the specifications described in 59.11. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant

NOTE— In this subclause and 59.5, the specifications for OMA have been derived from extinction ratio and average launch power (min) or receiver sensitivity (max). The calculation is explained in 60.8.6.

59.4.1 Transmitter optical specifications

The 1000BASE-LX10 transmitter shall meet the specifications defined in Table 59–5 per measurement techniques described in 59.9. To ensure that the specifications of Table 59–5 are met with MMF links, the 1000BASE-LX10 transmitter output shall be coupled through a single-mode fiber offset-launch mode-conditioning patch cord, as defined in 59.11.5.

The maximum RMS spectral width vs. center wavelength for 1000BASE-LX10 is shown in Table 59–6. Theequation used to generate these values is included in 59.9.2. The values in bold are normative, the others informative.

59.4.2 Receiver optical specifications

The 1000BASE-LX10 receiver shall meet the specifications defined in Table 59–7 per measurement techniques defined in 59.9. The receive sensitivity includes the extinction ratio penalty.

59.5 PMD to MDI optical specifications for 1000BASE-BX10-D and 1000BASE-BX10-U

The operating range for 1000BASE-BX10-D and 1000BASE-BX10-U is defined in Table 59–1. A 1000BASE-BX10 compliant transceiver operates over all single-mode fibers listed in Table 59–1. A trans-

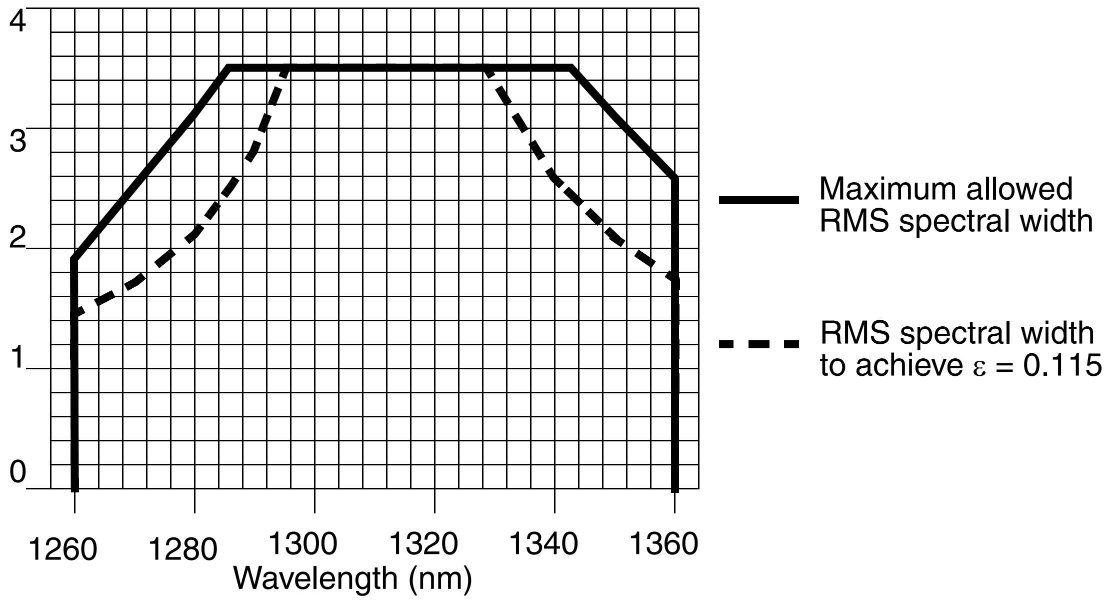

Figure 59–3—1000BASE-LX-10 Transmitter spectral limits

Table 59–5—1000BASE-LX10 transmit characteristics

Description	SMF	50 µm MMF	62.5 µm MMF	Unit
Transmitter type	Longwave Laser			
Signaling speed (range)	1.25 ± 100 ppm			GBd
Operating wavelength range[a]	1260 to 1360			nm
T rise /T fall (max, 20-80% response time)	0.30			ns
RMS spectral width (max)	See middle column of Table 59–6			nm
Average launch power (max)	-3			dBm
Average launch power (min)	-9.5	-11.0	-11.0	dBm

Table 59–5—1000BASE-LX10 transmit characteristics

Description	SMF	50 µm MMF	62.5 µm MMF	Unit
Average launch power of OFF transmitter (max)	-45			dBm
Extinction ratio (min)	6			dB
RIN (max)	-120			dB/Hz
Optical return loss tolerance (max)	12			dB
Launch OMA (min)	130 (-8.7)	100 (-10.2)	100 (-10.2)	µW (dBm)
Transmitter eye mask definition {X1, X2,Y1, Y2, Y3}	0.22, 0.375, 0.20, 0.20, 0.30			UI
Decision timing offsets for transmitter and dispersion penalty (min)	±65			ps
Transmitter reflectance (max)	-12			dB
Transmitter and dispersion penalty, TDP (max)	TBD	TBD	TBD	dB
Differential delay, reference receiver for TDP (min)	NA	300	300	ps

[a]The great majority of the transmitted spectrum must fall within the operating wavelength range.

Table 59–6—1000BASE-LX10 and 1000BASE-BX10 transmitter spectral limits

Center wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve epsilon ≤0.115 (Informative)
nm	**nm**	**nm**
1260	**1.90**	1.43
1270	**2.52**	1.72
1280	**3.13**	2.14
1286	**3.50**	2.49
1290		2.80
1297		3.50
1329		
1340		2.59
1343		2.41
1350	**3.06**	2.09
1360	**2.58**	1.76
1480 to 1500	**0.88**	0.60

[a]These limits for the 1000BASE-LX10 transmitter are illustrated in Figure 59–4. Limits at intermediate wavelengths may be found by interpolation.

Table 59–7—1000BASE-LX10 receive characteristics

Description	Value	Unit
Signaling speed (range)	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	nm
Average receive power (max)	-3	dBm
Receive Sensitivity (max)	-20	dBm
Receiver sensitivity as OMA (max)	12 (-19.0)	μW (dBm)
Receiver Reflectance (max)[a]	-12	dB
Stressed Receive Sensitivity (max)[b]	-18.4	dBm
Stressed receiver sensitivity as OMA (max)	17 (-17.6)	μW (dBm)
Vertical eye-closure penalty (min)	3.6	dB
Receive electrical 3 dB upper cutoff frequency (max)	1500	MHz
Signal detect threshold (min)	-45	dBm
Stressed eye jitter (min)[c]	TBD	UI pk-pk
Jitter corner frequency	637	kHz
Sinusodial jitter limits for stressed receiver conformance test (min, max)	TBD	

[a]See 1.4.n*ref* for definition of reflectance.
[b]The stressed receiver sensitivity recommendation is informative not mandatory
[c]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver..

ceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE— In this subclause and 59.4, the specifications for OMA have been derived from extinction ratio and average launch power (min) or receiver sensitivity (max). The calculation is explained in 60.8.6.

59.5.1 Transmit optical specifications

The 1000BASE-BX10-D and 1000BASE-BX10-U transmitter shall meet the specifications defined in Table 59–8 per measurement techniques described in 59.9.

59.5.2 Receiver optical specifications

The 1000BASE-BX10-D and 1000BASE-BX10-U receiver shall meet the specifications defined in Table 59–9 per measurement techniques defined in 59.10. The receive sensitivity includes the extinction ratio penalty.

59.6 Illustrative 1000BASE-LX10 and 1000BASE-BX10 channel and penalties

The illustrative channel and penalties for 1000BASE-LX10 and 1000BASE-BX10 PMDs are shown in Table 59–10.

NOTE—The budgets include an allowance for -12 dB reflection at the receiver.

Table 59–8—1000BASE-BX10-D and 1000BASE-BX10-U transmit characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Transmitter type	Longwave Laser		
Signaling speed (range)	1.25 ± 100 ppm		GBd
Operating wavelength range[a]	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	See Table 59–6		nm
Average launch power (max)	-3		dBm
Average launch power (min)	-9		dBm
Average launch power of OFF transmitter (max)	-45		dBm
Extinction ratio (min)	6		dB
RIN (max)	-120		dB/Hz
Optical return loss tolerance (max)	12		dB
Launch OMA	151 (-8.2)		µW (dBm
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	0.22, 0.375, 0.20, 0.20, 0.30		UI
Transmitter reflectance (max)	-12		dB
Transmitter and dispersion penalty, TDP (max)	TBD	TBD	dB
Decision timing offsets for transmitter and dispersion penalty (min)	±0.1		UI

[a]The great majority of the transmitted spectrum must fall within the operating wavelength range.

Table 59–9—1000BASE-BX10-D and 1000BASE-BX10-U receive characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Signaling speed (range)	1.25 ± 100 ppm		GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Average receive power (max)	-3		dBm
Receive Sensitivity (max)	-20		dBm

Table 59–9—1000BASE-BX10-D and 1000BASE-BX10-U receive characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Receiver sensitivity as OMA (max)	TBD		µW (dBm)
Receiver Reflectance (max)	-12		dB
Stressed Receive Sensitivity (max)[a]	-18.4		dBm
Stressed receiver sensitivity as OMA (max)	12 (-19)		µW (dBm)
Vertical eye-closure penalty (min)	2.6		dB
Receive electrical 3 dB upper cutoff frequency (max)	1500		MHz
Signal detect threshold (min)	-45		dBm
Stressed eye jitter (min)[b]	TBD		UI pk-pk
Jitter corner frequency	637		kHz
Sinusodial jitter limits for stressed receiver conformance test (min, max)	TBD		UI

[a]The stressed receiver sensitivity recommendation is informative not mandatory
[b]Vertical eye closure penalty and jitter specifications are informative.

Table 59–10—Illustrative 1000BASE-LX10 and 1000BASE-BX10 channel and penalties

PMD type	1000BASE-LX10		1000BASE-BX10-U	1000BASE-BX10-D	Unit
Fiber type	B1.1, B1.3 SMF	50µm, 62.5µm MMF	B1.1, B1.3 SMF		
Measurement wavelength for fiber	1310	1300	1310	1550	nm
Nominal distance	10	0.55	10		km
Available power budget	10.5	9.0	11.0		dB
Maximum channel insertion loss[a]	6.0	2.4	6.0	5.5	dB
Allocation for penalties[b]	4.5	6.6	5.0	5.5	dB

[a]The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components.
[b]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worse case operating wavelength is considered a penalty.

59.7 Jitter specifications for 1000BASE-LX10 on MMF(informative)

Numbers in the Table 59–12 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. All values are informative.

Table 59–11—Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties

Description	100BASE-LX10	100BASE-BX10		Unit
Fiber type	B1.1, B1.3 SMF			
Measurement wavelength for fiber	1310	1550	1310	nm
Nominal distance	10			km
Available power budget	10	13.3		dB
Maximum channel insertion loss[a]	6.0	5.5	6.0	dB
Allocation for penalties[b]	4.0	7.8	7.3	dB

[a]The maximum channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components.
[b]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst-case operating wavelength is considered a penalty.

Table 59–12—1000BASE-LX10 jitter budget on MMF(informative)

	Total jitter		Deterministic jitter	
Reference Point	UI	ps	UI	ps
TP1	0.240	192	0.100	80
TP1 to TP2	0.284	227	0.100	80
TP2	0.431	345	0.200	160
TP2 to TP3	0.170	136	0.050	40
TP3	0.510	408	0.250	200
TP3 to TP4	0.332	266	0.212	170
TP4	0.749	599	0.462	370

59.8 Jitter specifications for 1000BASE-LX10 and 1000BASE-BX10 on SMF (informative)

Numbers in the Table 59–13 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. All values are informative.

59.9 Optical measurement requirements

All optical measurements except TDP and RIN shall be made through a short patch cable, between 2 and 5 m in length.

59.9.1 Frame based test patterns

The frame based test patterns defined here are suitable for testing all Clause 58*ref* and 59 PMDs. The test suite and the recommended patterns are shown below.

Table 59–13—1000BASE-LX10 and 1000BASE-BX10 jitter budget on SMF (informative)

	Total jitter		Deterministic jitter	
Reference Point	UI	ps	UI	ps
TP1	0.240	192	0.100	80
TP1 to TP2				
TP2				
TP2 to TP3				
TP3	0.510	408	0.250	200
TP3 to TP4				
TP4	0.749	599	0.462	370

Table 59–14—List of test patterns and tests

Test Pattern	Tests
Any valid 8B/10B encoded signal	Eye Mask Optical Power Extinction Ratio OMA Central Wavelength Spectral Width
Random Pattern Test Frame	Receiver Sensitivity Stressed Receiver Sensitivity Receiver 3dB Upper Cutoff Frequency TDP
Jitter Pattern Test Frame	All Jitter Tests
Test Pattern not Frame Based	RIN_xOMA

59.9.1.1 Frame Based Test Patterns

The following test patterns are intended for frame based testing of the 1000BASE-X PMDs of Clauses 58*ref* and 59. They are compliant Ethernet frames with adequate user defined fields to allow them to be routed through a system to the point of the test. The common portions of the frames are given in Table 59–15.

Two payloads are defined. the first is a random pattern broad spectral content and minimal peaking shown in Table 59–16. This pattern may be used for general testing.

The payload for the second pattern is shown in Table 59–17. This pattern has areas of high and low density to aggravate jitter susceptibility.

Table 59–15—Common Portion of Frame Based Test Pattern

Field	Number of Octets	Hexadecimal
Idle	7	55
SOF	1	D5
Destination Address	6	User Defined
Source Address	6	User Defined
Length / Type	2	User Defined
First Portion of MAC Client Data	32	User Defined
Second Portion of MAC Client Data	228	See Table 59–16 or Table 59–17
Frame Check Sequence	4	As required by frame

Table 59–16—Payload for Random Pattern Test Frame

Field	Number of octets	Hexadecimal
Second Portion of MAC Client Data	228	The 12 Octet field "BE D7 23 47 6B 8F B3 14 5E FB 35 59" repeated 19 times

Table 59–17—Payload for Jitter Pattern Test Frame

Field	Number of Octets	Hexadecimal
Low transition density	164	7E repeated 164 times
Transition from Low to High Density pattern	8	7E 7E 7E 74 7E AB B5 B5
High Transition Density	48	B5 repeated 48 times
Transition from High to Low Density Pattern	8	B5 5E A4 7E 7E 7E 7E 7E

Editors' Note: *To be removed prior to final publication.*
The above section of Frame based testing results from comment 1007 made against D1.3 and is for further study

59.9.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall be assured in relation to measurement procedures using an optical spectrum analyzer per ANSI/ EIA/ TIA- 455- 127, under modulated conditions using a valid 1000BASE-X signal.

Note 1: The great majority of the transmitted spectrum must fall within the operating range.The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

Note 2: The 20 dB width for SLM lasers is taken as 6.07 times the RMS width.

The interaction between the transmitter and the chromatic dispersion of the fiber is accounted for by a parameter ε (epsilon), which is defined as the product of 10e3 times the signaling speed (in GBd) times the path dispersion (in ps/nm) times the RMS spectral width (in nm).

$$\varepsilon = \text{dispersion} \times \text{length} \times \text{RMS spectral width} \times \text{signaling speed} \qquad \text{59-1}$$

A maximum ε close to 0.168 is imposed by column 2 of Table 59-5. If the spectral width is kept below the limits of column 3, ε will not exceed 0.115, and the chromatic dispersion penalty is expected to be below 2 dB. The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP) which is specified in Table 59-4 and described in 60.7.9 *ref*.

59.9.3 Optical power measurements

Optical power shall be measured using the methods specified in ANSI/EIA-455-95 [B7]. This measurement may be made with the node transmitting any valid encoded 8B/10B data stream.

59.9.4 Extinction ratio measurements

Extinction ratio is defined according to the methods specified in ANSI/TIA/EIA-526-4A with the node transmitting a repeating idle pattern I2 and with minimal back reflections into the transmitter, lower than -20 dB. This is defined in Clause 36*ref*, and is coded as /K28.5/D16.2/ which is binary 001111 1010 100100 0101 or 110000 0101 011011 0101.

59.9.5 OMA measurements (informative)

ref Clause 60.8.5 provides a reference technique for performing OMA measurements.

59.9.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The text in Clause 60.8.6 *ref* provides a reference to the reader. That clause is intended to inform on how the three quantaties OMA, extinction ratio, and mean power, are related to each other.

59.9.7 Relative intensity noise (RIN)

RIN shall be measured according to ANSI X3.230 [B20](FC-PH), Annex A, A.5, Relative intensity noise (RIN) measuring procedure. Per this FC-PH annex, “This procedure describes a component test which may not be appropriate for a system level test depending on the implementation.” RIN is referred to as RIN_{12} in the referenced standard.

59.9.8 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 59–4.

Normalized amplitudes of 0.0 and 1.0 represent the amplitudes of the logic ZERO and ONE respectively. 0 and 1 on the unit interval scale are to be determined by the eye crossing means. A clock recovery unit (CRU) may be used to trigger the scope for mask measurements. It should have a high frequency corner bandwidth of less than or equal to the jitter corner frequency specified in the transmitter table, and a slope of -20 dB/ decade.

The eye shall be meaured with repect to the mask of the eye using a fourth-order Bessel Thomson filter with the transfer function given by:

$$H(p) = \frac{105}{105 + 105y + 45y^2 + 10y^3 + y^4} \quad (59\text{-}1)$$

where,

$$y = 2.114p \; ; \quad p = \frac{j\omega}{\omega_r} \; ; \quad \omega_r = 2\pi f_r \; ; \quad f_r = 0.9375 GHz \qquad (59\text{-}2)$$

and where the filter response vs. frequency range for this fourth order Bessel Thomson filter is defined in ITU-T G.957,Table B.2 (STM-16 values), along with the allowed tolerances for its physical implementation.

NOTE 1- This Bessel Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions on the transmitter.

NOTE 2 - The fourth order Bessel Thomson filter is reactive. In order to surpress reflections, a 6 dB attenuator may be required at the filter input and/or output.

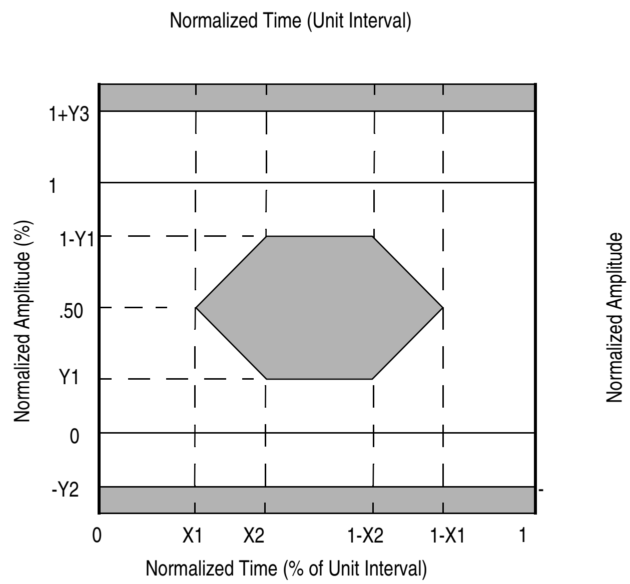

Figure 59–4—Transmitter eye mask definition

59.9.9 Transmit rise/fall characteristics

Optical response time specifications are based on unfiltered waveforms. Some lasers have overshoot and ringing on the optical waveforms, which, if unfiltered, reduce the accuracy of the 20-80% response times. For the purpose of standardizing the measurement method, measured waveforms shall conform to the mask defined in 59.9.8. If a filter is needed to conform to the mask, the filter response should be removed using the equation:

$$T_{rise,fall} = \sqrt{(T_{rise,fall,measured})^2 - (T_{rise,fall,filter})^2} \qquad 59\text{-}2$$

where the filter may be different for rise and fall. Any filter should have an impulse response equivalent to a fourth order Bessel Thomson filter. The fourth order Bessel Thomson filter describe in 59.9.8 may be a convenient filter for this measurement, however its low bandwidth adversely impacts the accuracy of the rise and fall time measurements.

59.9.10 Transmitter and dispersion penalty (TDP)

This measurement tests for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber, and for transmitter impairments with chromatic effects for a transmitter to be used with single mode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. meeting the separate requirements (e.g. eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The TDP limit shall be met. See *ref*60.8.9 for details of the measurement.

59.9.11 Receive sensitivity measurements

The receive sensitivity shall be measured using a worst-case extinction ratio penalty while sampling at the eye center. Stressed sensitivity is described in 59.9.14 and 60.8.11

59.9.12 Total jitter measurements (informative)

All total jitter measurements should be made according to the method in ANSI X3.230 [B20] (FC-PH), Annex A, A.4.2, *Active output interface eye opening measurement*. See also 60.8.12. Total jitter at TP2 should be measured utilizing a BERT (Bit Error Rate Test) test set. References to use of the Bessel-Thomson filter should substitute use of the Bessel-Thomson filter defined in this clause (see 59.9.8). The test should utilize the mixed frequency test pattern specified in 36A.3.

Total jitter at TP4 should be measured using the conformance test signal at TP3, as specified in 59.9.14. The optical power should be at the stressed receive sensitivity level in Table 59–7 for 1000BASE-LX10 and in Table 59–9 for 1000BASE-BX. This power level should be corrected if the extinction ratio differs from the specified extinction ratio (min). Measurements should be taken directly at TP4 without additional Bessel-Thomson filters.

Jitter measurement may use a clock recovery unit (commonly referred to in the industry as a “golden PLL”) to remove low-frequency jitter from the measurement as shown in Figure 59–5. The clock recovery unit has a low pass filter with 20 dB/decade rolloff with –3 dB point of 637 kHz. For this measurement, the recovered clock will run at the signaling speed. The golden PLL is used to approximate the PLL in the deserializer function of the PMA. The PMA deserializer is able to track a large amount of low-frequency jitter (such as drift or wander) below its bandwidth. This low-frequency jitter would create a large measurement penalty, but does not affect operation of the link.

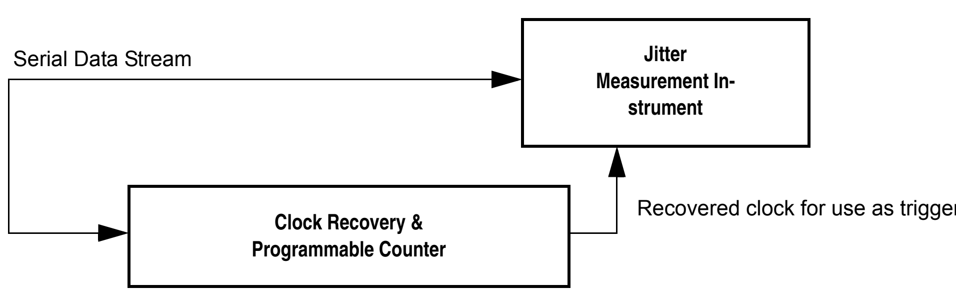

Figure 59–5—Utilization of clock recovery unit during measurement

59.9.13 Deterministic jitter measurement (informative)

Deterministic jitter should be measured according to ANSI X3.230-1994 [B20] (FC-PH), Annex A, A.4.3, DJ Measurement. The test utilizes the mixed frequency test pattern specified in 36A.3. This method utilizes a digital sampling scope to measure actual vs. predicted arrival of bit transitions of the 36A.3 data pattern (alternating K28.5 code-groups).

It is convenient to use the clock recovery unit described in 59.9.12 for purposes of generating a trigger for the test equipment. This recovered clock should have a frequency equivalent to 1/20th of the signaling speed.

59.9.14 Stressed receiver conformance test (informative)

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. The conformance test signal is conditioned by applying deterministic jitter and intersymbol interference. Receiver sensitivity is assured in relation to the measurement procedures of 60.8.11 *ref* and the specifications of Table 59–7 and Table 59–9, using the short continuous random test pattern defined in 36A. 5.

59.9.15 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency shall be measured as described below. The test setup is shown in Figure 59–6. The test is performed with a laser that is suitable for analog signal transmission. The laser is modulated by a digital data signal. In addition to the digital modulation, the laser is modulated with an analog signal. The analog and digital signals should be asynchronous. The data pattern to be used for this test is the short continuous random test pattern defined in 36A.5. The frequency response of the laser must be sufficient to allow it to respond to both the digital modulation and the analog modulation. The laser should be biased so that it remains linear when driven by the combined signals. Alternatively the two signals may be combined in the optical domain.

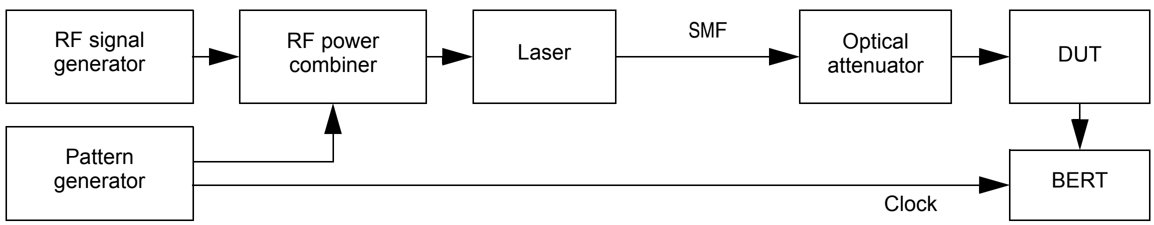

Figure 59–6—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency is measured using the following steps a) through e):

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator, RF power combiner, and laser source. Measure the laser's extinction ratio according to 59.9.4. With the exception of extinction ratio, the optical source shall meet the requirements of Clause 59.
b) Configure the test equipment as shown in Figure 59–6. Take care to minimize changes to the signal path that could affect the system frequency response after the calibration in step a. Connect the laser output with no RF modulation applied to the receiver under test through an optical attenuator and taking into account the extinction ratio of the source, set the optical power to a level that approximates the stressed receive sensitivity level in Table 59–7 for 1000BASE-LX10 and in Table 59–9 for 1000BASE-BX.
c) Locate the center of the eye with the BERT. Turn on the RF modulation while maintaining the same average optical power established in step b.

d) Measure the necessary RF modulation amplitude (in dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.

e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in “d” corrected with the calibration data in “a”) increases by 3 dB (electrical). If necessary, interpolate between the measured response values.

59.10 Environmental, safety and labeling specifications

59.10.1 General Safety

All equipment meeting this standard shall conform to IEC 60950.

59.10.2 Laser Safety

1000BASE-X optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825-1, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographical regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product’s laser, safety features, labeling, use, maintenance and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

59.10.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulations, be followed in every instance in which such practices are applicable.

59.10.4 Environment

Reference *ref*Annex 66A for additional environmental information.

59.10.5 PMD labelling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 1000BASE-BX10-U).

Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 59.10.2.

Compliant systems and field pluggable components shall be clearly labeled with the operating temperature range over which their compliance is ensured.

59.11 Characteristics of the fiber optic cabling

The 1000BASE-BX and 1000BASE-LX10 fiber optic cabling shall meet the dispersion and modal bandwidth specifications defined in IEC 60793-2 and ITU G.652, as shown in Table 59–18. The fiber cable attenuation is shown for information only; the end-to-end channel loss shall meet the requirements of Table 59–1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 59–7.

59.11.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 59–7

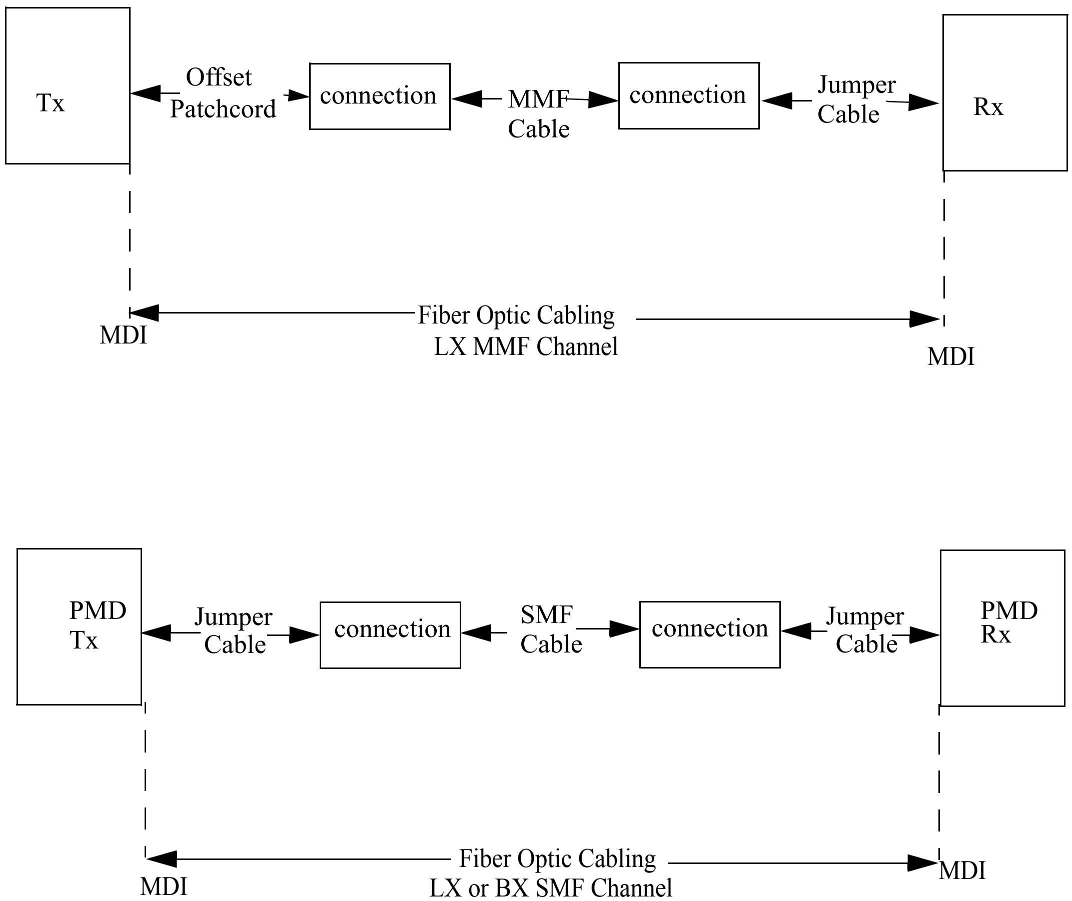

Figure 59–7—Fiber Optic Cable Model

The maximum channel insertion loss shall meet the requirements specified in Table 59–1. The minimum loss for 100BASE-LX10 and 100BASE-BX10 is zero. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion and reflections, meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A [B14], method B for multimode cabling and ANSI/TIA/EIA-526-7 [B15], method A-1 for single-mode cabling. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment.The term channel is used here for consistency with generic cabling standards.

59.11.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2 Type B1.1 (dispersion un-shifted single-mode fiber) and Type B1.3 (low water peak single-mode fiber) and ITU G.652 as noted in Table 59–18.

Table 59–18—Optical fiber and cable characteristics

Description[a]	B1.1, B1.3 SMF		50 µm MMF	62.5 µm MMF	Unit
Nominal fiber specification wavelength[b]	1310	1550	1300		nm
Fiber cable attenuation (max)[c]	0.4	0.35	1.5		dB/km
Modal Bandwidth (min; overfilled launch)	N/A		500		MHz· km
Zero dispersion wavelength[d]	$1300 \le \lambda_0 \le 1324$		$1295 \le \lambda_0 \le 1320$	$1320 \le \lambda_0 \le 1365$	nm
Dispersion slope (max)	0.093		0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0\text{-}1190)$ for $1295 \le \lambda_0 \le 1300$	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458\text{-}\lambda_0)$ for $1348 \le \lambda_0 \le 1365$	ps /nm^2 · km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]The wavelength specified is the nominal fiber specification wavelength which is the typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation values are informative. Attenuation for single-mode optical fiber cables is defined in ITU-T G.652 and for multimode fiber cables is defined in IS 11801.
[d]See IEC 60793 or G.652 for correct use of zero dispersion wavelength and dispersion slope.

59.11.3 Optical fiber connection

The maximum link distances for multimode fiber are calculated based on the allocation of 1.5dB total connection and splice loss. Connections with different loss characteristics may be used provided the requirements of Table 59–1 are met.

The maximum link distances for single mode fiber are calculated based on the allocation of 2 dB total connection and splice loss for 1000BASE-LX10 and 1000BASE-BX. Connections with different loss characteristics may be used provided the requirements of Table 59–1 are met.

The maximum discrete reflectance for multi-mode connections shall be less than -20 dB.

The maximum discrete reflectance for single mode connections shall be less than -26 dB.

59.11.4 Medium Dependent Interface (MDI)

The 1000BASE-LX10 or 1000BASE-BX is coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” as shown in Figure 59–7. Examples of an MDI include

(a) Connectorized fiber pigtail

(b) PMD receptacle

When the MDI is a remateable connection, it shall meet the interface performance specifications of IEC 61753-1-1, Fibre optic interconnecting devices and passive component performance standard - Part 1-1: General and guidance interconnecting devices (connectors).

Note: Compliance testing is done at TP2 and TP3, not at the MDI.

59.11.5 single-mode fiber offset-launch mode-conditioning patch cord for MMF operation of 1000BASE-LX10

This subclause specifies an example embodiment of a mode conditioner for 1000BASE-EX operation with MMF cabling. The MMF cabling should meet all of the specifications of Table 59-19 For 1000BASE-EX the mode conditioner consists of a single-mode fiber permanently coupled off-center to a graded index fiber. This example embodiment of a patch cord is not intended to exclude other physical implementations of offset-launch mode conditioners. However, any implementation of an offset-launch mode conditioner used for 1000BASE-EX shall meet the specifications of Table 59-19. The offset launch must be contained within the patch cord assembly and is not adjustable by the user. The requirements of this subclause are virtually identical to those of 38.11.4.

Table 59-19—single-mode fiber offset-launch mode conditioner specifications

Description	62.5 µm MMF	50 µm MMF	Unit
Maximum insertion loss	0.5	0.5	dB
Coupled Power Ratio (CPR)	28 < CPR < 40	12 < CPR < 20	dB
Optical center offset between SMF and MMF	17 < Offset < 23	10 < Offset < 16	µm
Maximum angular offset	1	1	degree

All patch cord connecting ferrules containing the single-mode-to-multimode offset launch shall have single-mode tolerances (IEC 61754-4 [B25] grade 1 ferrule).

The single-mode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall meet the requirements of 59.11.2. The multimode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall be of the same type as the cabling over which the 1000BASE-EX link is to be operated. If the cabling is 62.5 µm MMF then the MMF used in the construction of the mode conditioner should be of type 62.5 µm MMF. If the cabling is 50 µm MMF, then the MMF used in the construction of the mode conditioner should be of type 50 µm MMF.

Table 59-8 shows an example of an embodiment of the single-mode fiber offset-launch mode-conditioning patch cord. This patch cord consists of duplex fibers including a single-mode-to-multimode offset launch fiber connected to the transmitter MDI and a second conventional graded index MMF connected to the receiver MDI. The preferred configuration is a plug-to-plug patch cord since it maximizes the power budget margin of the 1000BASE-EX link. The single-mode end of the patch cord is labeled “To Equipment.” The multimode end of the patch cord is labeled “To Cable.” The color identifier of the single-mode fiber connector is blue. The color identifier of all multimode fiber connector plugs is beige. The patch cord assembly is labeled “Offset-launch mode-conditioning patch cord assembly.” Labelling identifies which size multimode fiber is used in the construction of the patch cord. The keying of this duplex optical plug ensures that the single-mode fiber end is automatically aligned to the transmitter MDI.

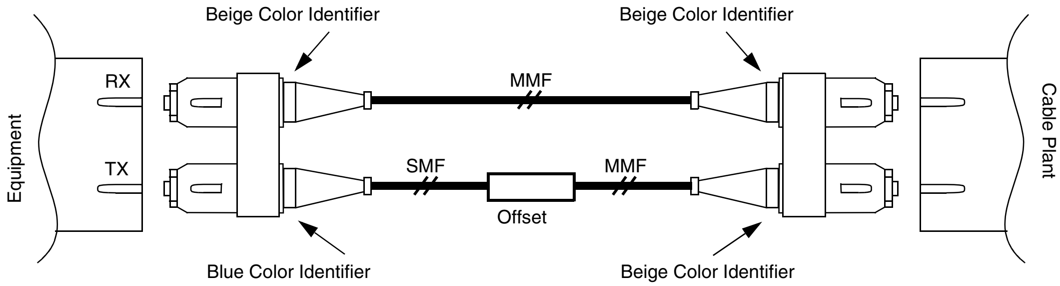

Figure 59-8—1000BASE-EX single-mode fiber offset-launch mode-conditioning patch cord assembly

59.12 Protocol Implementation Conformance Statement (PICS) proforma for Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 (Long Wavelength) and 1000BASE-BX10 (BiDirectional Long Wavelength)

59.12.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 59, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX10 and type 1000BASE-BX, shall complete the following Protocol Implementation Conformance Statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

59.12.2 Identification

59.12.2.1 Implementation identification

Supplier	
Contact point for enquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Names(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

59.12.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2003®, Clause 59, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX10 and 1000BASE-BX10
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2003®.)	

Date of Statement	

59.12.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*MD	MDIO capability	59.2	Registers and interface supported	O	Yes [ ] No [ ]
*HT	High temperature operation	59.1	XX to YY °C	O	Yes [ ] No [ ]
*LT	Low temperature operation	59.1	WW to ZZ °C	O	Yes [ ] No [ ]
*LX	1000BASE-LX10 PMD	59.1	Device supports long wavelength operation (nm).	O/1	Yes [ ] No [ ]
*BX-D	1000BASE-BX10-D PMD	59.1	Device supports long wavelength operation (nm).	O/1	Yes [ ] No [ ]
*BX-U	1000BASE-BX10-U PMD	59.1	Device supports long wavelength operation (nm).	O/1	Yes [ ] No [ ]
*INS	Installation / cable	59.11.2	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]
*OFP	Single-mode offset-launch mode-conditioning patch cord	59.11.5	Items marked with OFP include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]

Editors' Note: *To be removed prior to final publication.*
The temperature limit values of XX, YY, WW and ZZ in the above table are for discussion in the STF

59.12.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Integration with 1000BASE-X PCS and PMA	59.1		M	Yes [ ]
FN2	Transmit function	59.3.2	Convey bits requested by PMD_UNITDATA.request() to the MDI	M	Yes [ ]
FN3	Mapping between optical signal and logical signal for transmitter	59.3.2	Higher optical power is a logical 1.	M	Yes [ ]
FN4	Receive function	59.3.3	Convey bits received from the MDI to PMD_UNITDATA.indicate()	M	Yes [ ]
FN5	Mapping between optical signal and logical signal for receiver	59.3.3	Higher optical power is a logical 1.	M	Yes [ ]
FN6	Signal detect function	59.3.4	Report to the PMD service interface the message PMD_SIGNAL.indicate(SIGNAL_DETECT)	M	Yes [ ]
FN7	Signal detect behavior	59.3.4	Meets requirements of Table 59–4	M	Yes [ ]

59.12.3.2 PMD to MDI optical specifications for 1000BASE-LX10

Item	Feature	Subclause	Value/Comment	Status	Support
PML1	Transmitter meets specifications in Table 59–5	59.4.1	Per measurement techniques in 59.9	LX:M	Yes [ ] N/A [ ]
PML2	Transmitter eye measurement	59.4.1	Per 59.9.8	LX:M	Yes [ ] N/A [ ]
PML3	Offset-launch mode-conditioning patch cord	59.4.1	Required for LX multimode operation	LX:M	Yes [ ] N/A [ ]
PML4	Receiver meets specifications in Table 59–7	59.4.2	Per measurement techniques in 59.9	LX:M	Yes [ ] N/A [ ]

59.12.3.3 PMD to MDI optical specifications for 1000BASE-BX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
BD1	Transmitter meets specifications in Table 59–8		Per measurement techniques in 59.9	BD:M	Yes [ ] N/A [ ]
BD2	Receiver meets specifications in Table 59–9	59.5.2	Per measurement techniques in 59.9	BD:M	Yes [ ] N/A [ ]

59.12.3.4 PMD to MDI optical specifications for 1000BASE-BX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
BU1	Transmitter meets specifications in Table 59–8		Per measurement techniques in 59.9	BU:M	Yes [ ] N/A [ ]
BU2	Receiver meets specifications in Table 59–9	59.5.2	Per measurement techniques in 59.9	BU:M	Yes [ ] N/A [ ]

59.12.3.5 Optical Measurement Requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	Length of patch cord used for measurements	59.9	2 to 5 m	M	Yes [ ]
OR2	Center wavelength and spectral width measurement conditions	59.9.2	Using optical spectrum analyzer per ANSI/EIA/TIA-455-127-1991 [B8]	M	Yes [ ]
OR3	Center wavelength and spectral width measurement conditions	59.9.2	Under modulated conditions using a valid 1000BASE-X signal	M	Yes [ ]
OR4	Optical power measurement conditions	59.9.3	Per ANSI/EIA-455-95-1986 [B7]	M	Yes [ ]
OR5	Extinction ratio measurement conditions	59.9.4	Per ANSI/TIA/EIA-526-4A-1997 [B13] using patch cable per 59.9	M	Yes [ ]
OR6	RIN test methods	59.9.7	ANSI X3.230-1994 [B20] (FC-PH), Annex A, A.5 using patch cable per 59.9	M	Yes [ ]
OR7	Transmit eye mask measurement conditions	59.9.8	Using fourth-order Bessel-Thomson filter per 59.9.8, using patch cable per 59.9	M	Yes [ ]
OR8	Transmit rise/fall measurement conditions	59.9.9	Waveforms conform to mask in Figure 59–4, measure from 20% to 80%, using patch cable per 59.9	LX:M	Yes [ ]
OR9	Receive sensitivity measurement conditions	59.9.11	Worst-case extinction ratio penalty while sampling at the eye center using patch cable per 59.9	M	Yes [ ]
OM10	Transmitter and dispersion penalty measurement	60.8.9	As described in 60.8.9	M	Yes [ ]
OR11	Compliance test signal at TP3	59.9.14	Meets requirements of Figure 59–4	M	Yes [ ]
OR12	Compliance test signal at TP3	59.9.14	Pattern specified in 36A.5	M	Yes [ ]
OR13	Compliance test signal at TP3	59.9.14	DJ eye closure no less than 65 ps	M	Yes [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
OR14	Compliance test signal at TP3	59.9.14	Bandwidth of photodetector >2.5 GHz, and couple through 4th order Bessel-Thomson filter	M	Yes [ ]
OR15	Receiver electrical cutoff frequency measurement procedure	59.9.15	As described in 59.9.15	M	Yes [ ]
OR16	Optical source used for cutoff frequency measurement	59.9.15	With the exception of extinction ratio, meets requirements of Clause 59	M	Yes [ ]
OR17	Compliance with IEC 60950-1991	59.10.1		M	Yes [ ]
OR18	Laser safety compliance	59.10.2	Class 1	M	Yes [ ]
OR19	Laser safety compliance test conditions	59.10.2	IEC 60825-1	M	Yes [ ]
OR20	Documentation explicitly defines requirements and usage restrictions on the host system necessary to meet after certifications	59.10.2		M	Yes [ ]
OR21	Sound installation practices	59.10.3		INS:M	Yes [ ] N/A [ ]

59.12.3.6 Characteristics of the fiber optic cabling

Item	Feature	Subclause	Value/Comment	Status	Support
LI1	Fiber optic cabling	59.11.2	Meets specifications in Table 59–18	INS:M	Yes [ ] N/A [ ]
LI2	Return loss for multimode connections	59.11.3	> 20 dB	INS:M	Yes [ ] N/A [ ]
LI3	Return loss for single-mode connections	59.11.3	> 26 dB	INS:M	Yes [ ] N/A [ ]
LI4	Offset-launch mode-conditioning patch cord	59.11.5	Meet conditions of ref*38.11.4	OFP:M	Yes [ ] N/A [ ]
LI5	Single-mode ferrules in offset-launch mode-conditioning patch cords	59.11.5	IEC 61754-4: 1997 [B25] grade 1 ferrule	OFP:M	Yes [ ] N/A [ ]
LI6	Single-mode fiber in offset-launch mode-conditioning patch cords	59.11.5	Per 59.11.5	OFP:M	Yes [ ] N/A [ ]
LI7	Multimode fiber in offset-launch mode-conditioning patch cords	59.11.5	Same type as used in LX cable plant	OFP:M	Yes [ ] N/A [ ]

60. Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 (Long Wavelength) and 100BASE-BX10 (BiDirectional Long Wavelength)

Editors' Notes: *To be removed prior to final publication.*
ref is intended to highlight references outside of this clause that will be adjusted prior to publication

Clause 60.1.1 "Goals and objectives" to be removed prior to final publication.

When all test procedures are stable, some test procedure sections within 60.8, which are common to 58-60, will be moved to 59. If a test procedure is then identical to Clause 52, we may delete it here and refer to 52.

Add sentence '100BASE-LX10 and 100BASE-BX10 (Clauses 24 and 60) use one pair of single mode fibers, and a single, single mode fiber, respectively.' to 21.1.2 Physical Layer signaling systems

Normative References:
Check that ANSI/TIA/EIA-526-4A-1997 formerly [B13] is on the normative list

If used for RIN measurement in another clause, check that ANSI X3.230-1994 [B20](FC-PH) is on the normative list.

Add ANSI/EIA/TIA-455-127, currently [B8] of annex A, to the normative reference list.

Informative References:

Add FOTP-107 to the informative reference list.

Definitions (to be added to 1.4):
Does 1.4.62 center wavelength, "The average of two optical wavelengths at which the spectral radiant intensity is 50% of the maximum value. (See IEEE 802.3 Clause 11.)", agree with EIA/TIA-455-127?

Update 1.4.15 definition of 100BASE-X.

Reflectance: Ratio of reflected to incident power (better check this with other standards, books etc.). This is the inverse of return loss.

Update 1.4.129, and 1.4.237 to mention 1000BASE-LX.

Update 1.4.10 100BASE-FX definition to "IEEE 802.3 Physical Layer specification for a 100 Mb/s link over two multimode optical fibers. (See IEEE 802.3 Clauses 24 and 26.)"

1.4.m 100BASE-LX10: IEEE 802.3 Physical Layer specification for a 100 Mb/s link over two single mode optical fibers. (See IEEE 802.3 Clauses 24 and 60.)

1.4.n 100BASE-BX10: IEEE 802.3 Physical Layer specification for a 100 Mb/s link over one single mode optical fiber. (See IEEE 802.3 Clauses 24 and 60.)

Abbreviations (to be added to 1.5):
IFG - Inter Frame Gap
ORLT - Optical return loss tolerance

Revision History:

Draft 0.9 June 2002	Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.0 August 2002	Draft 1.0 for IEEE P802.3ah Task Force review.
Draft 1.1 October 2002	Draft 1.1 for IEEE P802.3ah Task Force review.
Draft 1.2 November 2002	Draft 1.2 for IEEE P802.3ah Task Force review.
Draft 1.3 January 2003	Draft 1.3 for IEEE P802.3ah Task Force review.
Draft 1.414 April 2003	Draft 1.4 for IEEE P802.3ah Task Force review.

60.1 Overview

The 100BASE-LX10 and 100BASE-BX10 PMD sublayers provide point-to-point 100 Mb/s Ethernet connections over pairs or individual single mode fibers respectively, up to 10 km long. They complement 100BASE-TX (twisted-pair cable, see Clause 25*ref*) and 100BASE-FX (multimode fiber, see Clause 26*ref*).

This clause specifies the 100BASE-LX10 PMD and 100BASE-BX10 PMDs and the medium, single-mode fiber. In order to form a complete physical layer, a PMD shall be integrated with the 100BASE-X PCS and PMA of Clause 24*ref*, and optionally integrated with the management functions which may be accessible through the Management Interface defined in Clause 22*ref* or 45*ref*, which are hereby incorporated by reference.

Table 60–1 shows the primary attributes of each PMD type.

Table 60–1—Classification of 100BASE-LX10 and 100BASE-BX10

Description	100BASE-LX10	100BASE-BX10-D	100BASE-BX10-U
Fiber type	B1.1, B1.3 SMF		
Number of fibers	2	1	
Typical transmit direction	N/A	Downstream	Upstream
Nominal transmit wavelength	1310 nm	1550 nm	1310 nm
Minimum range	0.5 m to 10 km		
Maximum channel insertion loss[a]	6.0 dB	5.5 dB	6.0 dB

[a]At the nominal wavelength

A 100BASE-LX10 link uses 100BASE-LX10 PMDs at each end while a 100BASE-BX10 link uses a 100BASE-BX10-U PMD at one end and a 100BASE-BX10-D PMD at the other. Typically the 1550 nm band is used to transmit away from the center of the network (“downstream”) and the 1310 nm band towards the center (“upstream”), although this arrangement, or the notion of hierarchy, is not required. The suffixes “D” and “U” indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions.

Two optional temperature ranges are defined; see Annex 66A*ref* for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

60.1.1 Goals and objectives

Support subscriber access network topologies:

Point to point on optical fiber

Such that:

Provide a family of physical layer specifications:

100BASE-X >= 10km over SM fiber

PHYs to have a BER better than or equal to 10^{-12} at the PHY service interface

60.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 60–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

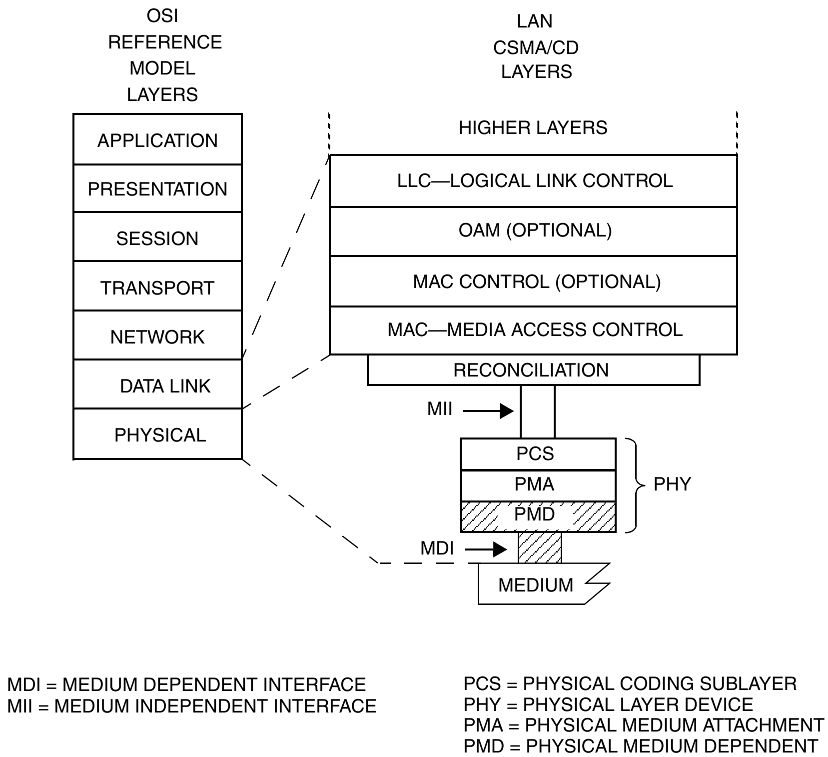

Figure 60–1—100BASE-LX10 and 100BASE-BX10 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

60.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

Basic terminology and conventions, see Clause 1.1*ref* and Clause 1.2*ref*.

Normative references, see Clause 1.3*ref*.

Definitions, see Clause 1.4*ref*.

Abbreviations, see Clause 1.5*ref*.

Informative references, see Appendix A*ref*.

Introduction to 100 Mb/s baseband networks, see Clause 21*ref*.

60.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 100BASE-LX10 and 100BASE-BX10 PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation.

The PMD service interface supports the exchange of NRZI encoded 4B/5B code-groups between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indicate

PMD_SIGNAL.indicate

NOTE—Primitives are described in 1.2.2*ref*.

NOTE—Delay requirements which affect the PMD layer are specified in 24.6*ref*.

60.1.4.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits where the tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 125 MBaud signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

60.1.4.2 PMD_UNITDATA.indicate

This primitive defines the transfer of data from the PMD to the PMA.

The semantics of the service primitive are PMD_UNITDATA.indicate(rx_bit). The data conveyed by PMD_UNITDATA.indicate is a continuous stream of bits where the rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

60.1.4.3 PMD_SIGNAL.indicate

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indicate(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indicate(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indicate(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the error rate objective.

60.2 PMD MDIO function mapping (informative)

The optional MDIO capability described in Clause 45*ref* defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it maps MDIO control variables to PMD control variables as shown in Table 60–2, and MDIO status variables to PMD status variables as shown in Table 60–3.

Table 60–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global transmit disable	Transmit disable register	1.9.0	PMD_global_transmit_disable

Table 60–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD receive signal detect	Receive signal detect register	1.10.0	PMD_global_signal_detect

60.3 PMD functional specifications

The 100BASE-X PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

60.3.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 60–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of single mode fiber. Unless specified otherwise, all transmitter measurements and tests defined in 60.8 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 60.8 are made at TP3.

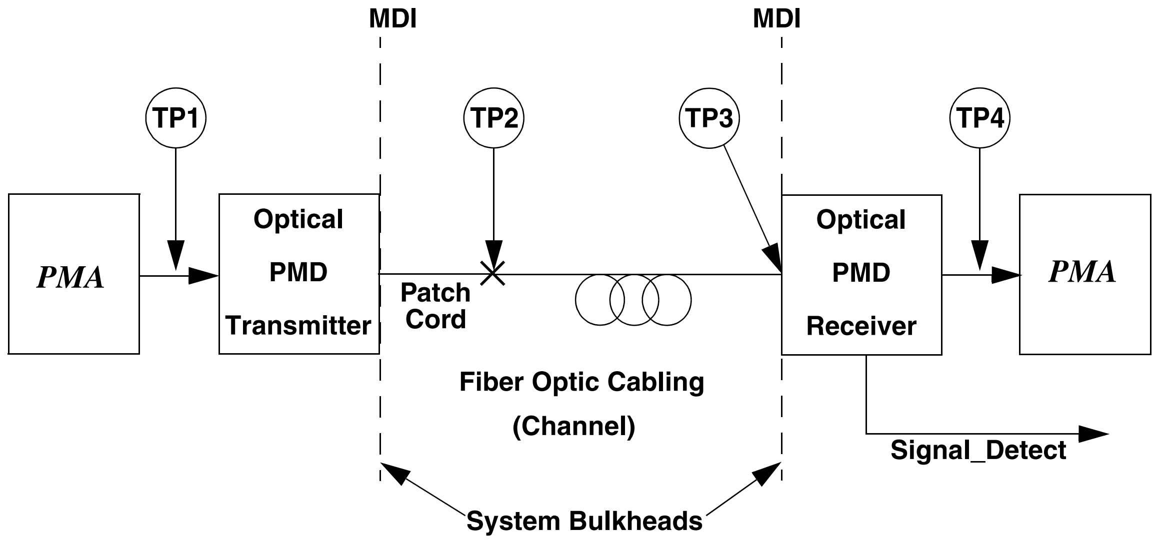

Figure 60–2—100BASE-X block diagram

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 100BASE-LX10, 100BASE-BX10-D, 100BASE-BX10-U, and 100BASE-FX.

60.3.2 PMD transmit function

The PMD transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

60.3.3 PMD receive function

The PMD receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indicate(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

60.3.4 100BASE-LX10 and 100BASE-BX10 signal detect function

The PMD signal detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indicate(SIGNAL_DETECT) which is signaled continuously. PMD_SIGNAL.indicate is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter for 100BASE-LX10 and 100BASE-BX10 shall be generated according to the conditions defined in Table 60–4. The PMD receiver is not required to verify whether a compliant 100BASE-LX10 or 100BASE-BX10 signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 60–4—100BASE-LX10 and 100BASE-BX10 SIGNAL_DETECT value definition

Receive conditions		Signal detect value
100BASE-LX10	**100BASE-BX10**	
Input optical power ≤ Signal detect threshold (min) in Table 60–6	Input optical power ≤ Signal detect threshold (min) in Table 60–8	FAIL
Input optical power ≥ Receiver sensitivity (max) in Table 60–6 AND compliant 100BASE-LX10 signal input	Input optical power ≥ Receiver sensitivity (max) in Table 60–8 AND compliant 100BASE-BX10 signal input at the specified receiver wavelength	OK
All other conditions		Unspecified

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the signal detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

60.4 PMD to MDI optical specifications for 100BASE-LX10

The operating range for 100BASE-LX10 is defined in Table 60–1. A 100BASE-LX10 compliant transceiver operates over the media types listed in Table 60–1 according to the specifications described in Clause 60.10. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE— In this subclause and 60.5, the specifications for OMA have been derived from extinction ratio and average launch power (min) or receiver sensitivity (max). The calculation is explained in 60.8.6.

60.4.1 Transmitter optical specifications

The 100BASE-LX10 transmitter shall meet the specifications defined in Table 60–5 per measurement techniques described in 60.8.

> ***Editors' Note:*** *To be removed prior to final publication.*
> Further tightening of the mask may be required and comments are welcome.

60.4.2 Receiver optical specifications

The 100BASE-LX10 receiver shall meet the specifications defined in Table 60–6 per measurement techniques defined in 60.8. The receiver sensitivity includes the extinction ratio penalty.

60.5 PMD to MDI optical specifications for 100BASE-BX10

The operating range for 100BASE-BX10 is defined in Table 60–1. A 100BASE-BX10-D or 100BASE-BX10-U compliant transceiver operates over the media types listed in Table 60–1 according to the specifica-

Table 60–5—100BASE-LX10 transmit characteristics

Description	Type B1.1, B1.3 SMF	Unit
Transmitter type	Longwave laser	
Signaling speed (range)	125 ± 50 ppm	MBd
Operating wavelength range[a]	1260 to 1360	nm
RMS spectral width (max)	7.7	nm
Average launch power (max)	-8	dBm
Average launch power (min)	-15	dBm
Average launch power of OFF transmitter (max)	-45	dBm
Extinction ratio (min)	5	dB
$RIN_{12}OMA$[b] (max)	-110	dB/Hz
Optical return loss tolerance (max)	12	dB
Launch OMA (min)	33.1 (-14.8)	µW (dBm)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3, Y4}	{0.25, 0.35, 0.4, 0.35, 0.38, 0.5, 0.65}	UI
Transmitter and dispersion penalty (max)	4.5	dB
Decision timing offsets for transmitter and dispersion penalty (min)	±1.2 to ±1.6 (TBD)	ns

[a]The great majority of the transmitted spectrum must fall within the operating wavelength range.
[b]The $RIN_{12}OMA$ recommendation is informative not mandatory.

Table 60–6—100BASE-LX10 receive characteristics

Description	Type B1.1, B1.3 SMF	Unit
Signaling speed (range)	125 ± 50 ppm	MBd
Operating wavelength range	1260 to 1360	nm
Average received power[a] (max)	-8	dBm

Table 60–6—100BASE-LX10 receive characteristics

Description	Type B1.1, B1.3 SMF	Unit
Receiver sensitivity (max)	-25	dBm
Receiver sensitivity as OMA (max)	3.3 (-24.8)	µW (dBm)
Receiver reflectance[b] (max)	-12	dB
Stressed receiver sensitivity[c]	-21.3	dBm
Stressed receiver sensitivity as OMA (max)	7.8 (-21.1)	µW (dBm)
Vertical eye-closure penalty[d]	3.7	dB
Stressed eye jitter (min)		UI pk-pk
Jitter corner frequency	20	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	TBD	UI
Signal detect threshold (min)	-45	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average received power (max) plus at least 1 dB.
[b]See 1.4.n*ref* for definition of reflectance.
[c]The stressed receiver sensitivity recommendation is informative not mandatory.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

tions described in Clause 60.10. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE— In this subclause and 60.4, the specifications for OMA have been derived from extinction ratio and average launch power (min) or receiver sensitivity (max). The calculation is explained in 60.8.6.

60.5.1 Transmit optical specifications

The 100BASE-BX10 transmitters shall meet the specifications defined in Table 60–7 per measurement techniques described in 60.8.

> ***Editors' Note:*** *To be removed prior to final publication.*
> Further tightening of the mask may be required and comments are welcome.

60.5.2 Receiver optical specifications

The 100BASE-BX10 receivers shall meet the specifications defined in Table 60–8 per measurement techniques defined in 60.8. The receiver sensitivity includes the extinction ratio penalty.

60.6 Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties (informative)

Illustrative channels and penalties for 100BASE-LX10 and 100BASE-BX10 are shown in Table 60–9.

NOTE— The budgets include an allowance for -12 dB reflection at the receiver.

Table 60–7—100BASE-BX10 transmit characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Transmitter type	Longwave laser		
Signaling speed (range)	125 ± 50 ppm		MBd
Operating wavelength range[a]	1480 to 1580	1260 to 1360	nm
RMS spectral width (max)	4.6	7.7	nm
Average launch power (max)	-8		dBm
Average launch power (min)	-14		dBm
Average launch power of OFF transmitter (max)	-45		dBm
Extinction ratio (min)	6.6		dB
$RIN_{12}OMA$[b] (max)	-110		dB/Hz
Optical return loss tolerance (max)	12		dB
Launch OMA (min)	51.0 (-12.9)		µW (dBm)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3, Y4}	{0.25, 0.35, 0.4, 0.35, 0.38, 0.5, 0.65}		UI
Transmitter and dispersion penalty (max)	4.5		dB
Decision timing offsets for transmitter and dispersion penalty (min)	±1.2 to ±1.6 (TBD)		ns

[a]The great majority of the transmitted spectrum must fall within the operating wavelength range.
[b]The $RIN_{12}OMA$ recommendation is informative not mandatory.

Table 60–8—100BASE-BX10 receive characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Signaling speed (range)	125 ± 50 ppm		MBd
Operating wavelength range[a]	1260 to 1360	1480 to 1600	nm
Average received power[b] (max)	-8		dBm

Table 60–8—100BASE-BX10 receive characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Receiver sensitivity (max)	-29.2		dBm
Receiver sensitivity as OMA (max)	1.55 (-28.1)		µW (dBm)
Receiver reflectance[c] (max)	-12		dB
Stressed receiver sensitivity[d]	-25.4		dBm
Stressed receiver sensitivity as OMA (max)	3.7 (-24.3)		µW (dBm)
Vertical eye-closure penalty[e]	3.8		dB
Stressed eye jitter (min)			UI pk-pk
Jitter corner frequency	20		kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	TBD		UI
Signal detect threshold (min)	-45		dBm

[a]The receiver wavelength range of 100BASE-BX10-U is defined up to 1600 nm to achieve backward compatibility with existing implementations of 100 Mb/s bi-directional optics with a transmit center wavelength of 1500 nm.
[b]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the Average received power (max) plus at least 1 dB.
[c]See 1.4.n*ref* for definition of reflectance.
[d]The stressed receiver sensitivity recommendation is informative not mandatory.
[e]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

Table 60–9—Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties

Description	100BASE-LX10	100BASE-BX10-D	100BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF			
Measurement wavelength for fiber	1310	1550	1310	nm
Nominal distance	10			km
Available power budget	10	13.3		dB
Maximum channel insertion loss[a]	6.0	5.5	6.0	dB
Allocation for penalties[b]	4.0	7.8	7.3	dB

[a]The maximum channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components.
[b]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst-case operating wavelength is considered a penalty.

60.7 Jitter at TP1 and TP4 for 100BASE-LX10 and 100BASE-BX10 (informative)

Numbers in the Table 60–10 represent high-frequency jitter (above 20 kHz) and do not include low frequency jitter or wander. The informative Table 60–10 shows jitter specifications which may be of interest to implementers. High probability jitter at TP2 is constrained by the eye mask. Total jitter at TP3 (and therefore at TP2 also) is constrained by the error detector timing offsets. High levels of high probability jitter at TP2, TP3 and TP4 are expected, caused by high probability baseline wander, and values in the range of 0.3 to 0.4 UI have been considered. The jitter difference between TP2 and TP3 is expected to be lower than for higher speed PMDs.

Table 60–10—100BASE-LX10 and 100BASE-BX10 jitter budget (informative)

	Total jitter		Deterministic jitter	
Reference point	**UI**	**ns**	**UI**	**ns**
TP1	0.09	0.72	0.05	0.40
TP2 and TP3	Use TDP methodology in Clause 60.8.9.			
TP4	TBD	TBD	TBD	TBD

60.8 Optical measurement requirements

All optical measurements except TDP and RIN shall be made through a short patch cable, between 2 and 5 m in length.

NOTE— 60.8.5, 60.8.6, 60.8.7, 60.8.9, 60.8.10, 60.8.11, and 60.8.12 apply to Clauses 58*ref*, 59*ref*, and 60*ref*. Clause 59*ref* (1000BASE-LX10) uses multimode fiber, although Clauses 60*ref* (100BASE-LX10 and 100BASE-BX10) and 58*ref* (1000BASE-PX10 and 1000BASE-PX20) do not.

60.8.1 Test patterns

Compliance is to be achieved in normal operation. Transmit eye mask and sensitivity are to be assured against the test pattern defined below. This represents an extremely untypical pattern. The BER in service can be expected to be lower than with the test pattern. In this clause, extinction ratio, OMA and RIN_xOMA are referred to the idle pattern (1010 for 4B/5B NRZI).

The test pattern shall be constructed as follows.

A test pattern for base line wander is composed of a sequence of three frames continuously repeated. Each frame has a 1500 octet length client data field and a zero length pad field. The contents of the destination address, source address, length/type fields and the first 32 octets of the client data field are at the discretion of the tester and may be implementation specific. The remaining 1468 octets of the client data field are filled with symbols with an even number of ones in the 4B/5B encoded data prior to NRZI transmission as shown in Table 60–11.

Frames are separated by a near minimum inter-frame gap (IFG) of 14 octets.

Within the limits of the three bit maximum run length of the 4B/5B code this sequence gives a near worst case ISI pattern and provides alternating periods of high and low transition density to test CDR performance.

The first 32 octets of the client data field are configured such that, after the frame check sequence (FCS) is added, there are an even number of ones in the first two packets and an odd number of ones in the third packet. This results in a six frame sequence with three frames containing near 40% ones density and three frames with near 60% ones density.

When transmitted with a near minimum inter-frame gap the resulting data stream has baseline wander at 1.35 kHz.

> ***Editors' Note:*** *To be removed prior to final publication.*
> Can this pattern be used by higher layer protocols as legal frames? The 32 octet element may be extended to allow for IP headers.

> ***Editors' Note:*** *To be removed prior to final publication.*
> It is hoped that an unbalanced payload can be found which is just as unbalanced as the example but provides a more stringent jitter test after the philosophy of 48A.5 Continuous jitter test pattern (CJPAT).

Table 60–11— Example unbalanced pattern

	Number of octets	Hexa-decimal	TXD<3:0>		4B/5B encoded		NRZI encoded			
Order; Mark ratio			1st nibble	2nd nibble	1st code-group[a]	2nd code-group	40%		60%	
Item										
Idle	14	Idle	Idle	Idle	11111	11111	10101	01010	01010	10101
Preamble	7	55	0101	0101	01011	01011	01101	10010	10010	01101
Start of frame delimiter	1	D5	0101	1101	01011	11011	01101	01101	10010	10010
Destination address[b]	6	FF	1111	1111	11101	11101	01001	01001	10110	10110
Source address	6	(variable or TBD)	0000	0000	11110	11110	01011	01011	10100	10100
Length/type	2	05	0101	0000	01011	11110	10010	10100	01101	01011
		FF	1111	1111	11101	11101	10110	10110	01001	01001
Implementa-tion specific (example)	32	00	0000	0000	11110	11110	10100	10100	01011	01011
		00	0000	0000	11110	11110	10100	10100	01011	01011
Low transition density	968	42	0010	0100	10100	01010	11000	01100	00111	10011
		24	0100	0010	01010	10100	01100	11000	10011	00111

Table 60–11— Example unbalanced pattern

	Number of octets	Hexa-decimal	TXD<3:0>		4B/5B encoded		NRZI encoded			
Order; Mark ratio			**1st nibble**	**2nd nibble**	**1st code-group** [a]	**2nd code-group**	**40%**		**60%**	
Mixed	8	00	0000	0000	11110	11110	10100	10100	01011	01011
		D2	0010	1101	10100	11011	11000	10010	00111	01101
High transition density	484	07	0111	0000	01111	11110	01010	10100	10101	01011
		70	0000	0111	11110	01111	10100	01010	01011	10101
Mixed	8	00	0000	0000	11110	11110	10100	10100	01011	01011
		D2	0010	1101	10100	11011	11000	10010	00111	01101
Frame check sequence 1	4	TBD								
Frame check sequence 2		TBD								
Frame check sequence 3		TBD								
Frame check sequence 4		TBD								

[a]The five bit code-groups are transmitted left most bit first.
[b]The example destination address is the multicast address.

60.8.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall be assured in relation to measurement procedures using an optical spectrum analyzer per ANSI/EIA/TIA-455-127 [B8], under modulated conditions using a valid 100BASE-X signal.

NOTE—The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

60.8.3 Optical power measurements

Optical power shall be measured using the methods specified in ANSI/EIA-455-95 [B7]. This measurement may be made with the node transmitting any valid balanced 4B/5B NRZI encoded data stream.

60.8.4 Extinction ratio measurements

Extinction ratio shall be measured using the methods specified in ANSI/TIA/EIA-526-4A [B13]. This measurement is made with the node transmitting the 4B/5B NRZI encoded idle (10101...) pattern. The extinction ratio is measured with minimal back reflections into the transmitter, lower than -20 dB.

60.8.5 Optical modulation amplitude (OMA) measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The following clause is intended to inform on how the OMA measurement is performed.

In this clause, OMA is the difference in optical power for “1” and “0” levels of the optical signal in an idle (10101... for 100BASE-LX10 and 100BASE-BX10) sequence. It may be found using waveform averaging or histogram means. The measurement is recommended to be equivalent to that described below.

The recommended technique for measuring optical modulation amplitude is illustrated in Figure 60–3. A fourth-order Bessel-Thomson filter as specified for measuring the transmitter concerned is to be used with the O/E converter. The measurement system consisting of the O/E converter, the filter and the oscilloscope is calibrated at the appropriate wavelength for the transmitter under test.

With the device under test transmitting the idle pattern, use the following procedure to measure optical modulation amplitude:

a) Configure the test equipment as illustrated in Figure 60–3.
b) Measure the mean optical power P_1 of the logic “1” as defined over the center 20% of the time interval, here 1 UI long, where the signal is in the high state.
c) Measure the mean optical power P_0 of the logic “0” as defined over the center 20% of the time interval, here 1 UI long, where the signal is in the low state.
d) OMA = P_1 - P_0.

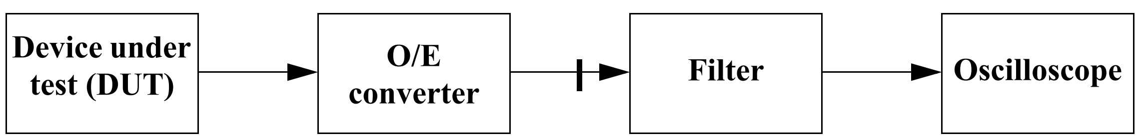

Figure 60–3—Recommended test equipment for measurement of optical modulation amplitude

A method of approximating OMA is shown in Figure 60–9.

Similarly, the optical power measure A_N is to be measured with a square wave pattern consisting of four to eleven consecutive ones followed by an equal run of zeros. Five ones followed by five zeroes is convenient (the /H/ code-group in 24*ref*, or K28.7 in 1000BASE-X which is the “Low-frequency test pattern” of 36A.2*ref*). The OMA of 52 is A_N, and OMA here may differ.

NOTE— This OMA measurement procedure applies to Clauses 58*ref*, 59*ref* and 60*ref*.

60.8.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The following clause is intended to inform on how the three quantities OMA, extinction ratio, and mean power, are related to each other.

Optical modulation amplitude (OMA) is the difference between light levels for “1” and “0”. Extinction ratio is the ratio between light levels for “1” and “0”. If a signal contains equal density of “1” and “0” bits, and does not suffer from duty cycle distortion, the mean power is close to the mean of the light levels for “1” and “0”.

$$OMA = P_1 - P_0 \tag{60-1}$$

OMA may be expressed in Watts or dBm.

$$ER = \frac{P_1}{P_0} \tag{60-2}$$

Extinction ratio may be expressed in dB, as $10 \cdot \log10\ (P_1 / P_0)$, or directly as a ratio. Sometimes extinction ratio is defined as P_0 / P_1.

$$P_{mean} \approx \frac{P_1 + P_2}{2} \tag{60-3}$$

Mean power may be expressed in Watts or dBm.

P_1 and P_0 are usually measured with a standardized instrument bandwidth to reduce the effects of overshoot. It should be noted that the values of P_1 and P_0 depend on the measurement technique and pattern to be used, which vary with PMD type. For some PMD types, e.g. 10GBASE, different patterns leading to different values of P_1 and P_0 are used for OMA on the one hand, and extinction ratio on the other.

Aside from these differences:

$$P_1 \approx 2 \times P_{mean} \times \frac{ER}{ER + 1} \tag{60-4}$$

$$P_0 \approx 2 \times \frac{P_{mean}}{ER + 1} \tag{60-5}$$

$$OMA \approx 2 \times P_{mean} \times \frac{ER - 1}{ER + 1} \tag{60-6}$$

Receiver sensitivity, which is an optical power, can be expressed in OMA or mean power terms according to the same relations.

NOTE— The OMA relationship to extinction ratio and power measurements applies to Clauses 58*ref*, 59*ref* and 60*ref*.

60.8.7 Relative intensity noise optical modulation amplitude (RIN_xOMA) measuring procedure

This procedure describes a component test that may not be appropriate for a system level test depending on the implementation. If used, the procedure shall be performed as described in 60.8.7.1, 60.8.7.2, and 60.8.7.3.

NOTE— This RIN_xOMA measurement procedure applies to Clauses 58*ref*, 59*ref* and 60*ref*.

60.8.7.1 General test description

The test arrangement is shown in Figure 60–4. The optical path between the Device Under Test (DUT) and the detector has a single discrete reflection with the specified optical return loss as seen by the DUT.

Both the OMA power and noise power are measured by AC coupling the O/E converter into the electrical power meter. If needed, an amplifier may be used to boost the signal to the power meter. A low pass filter is used between the photo detector and the power meter to limit the noise measured to the passband appropriate to the data rate of interest. In order to measure the noise, the modulation to the DUT is turned off.

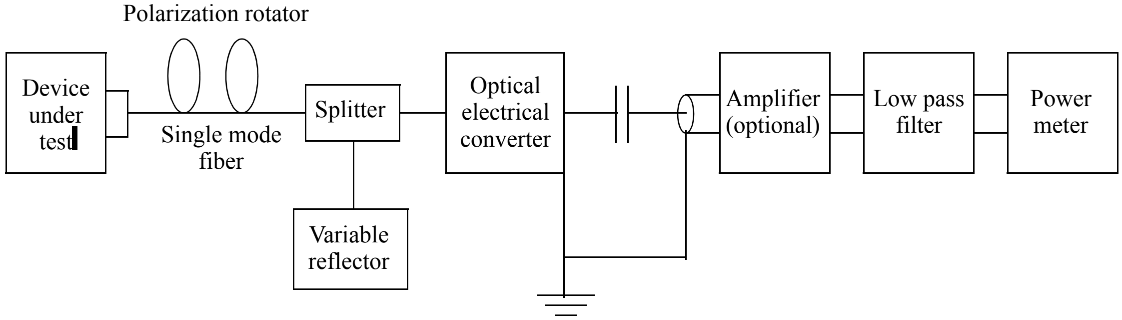

Figure 60–4—RIN$_x$OMA measurement setup

60.8.7.2 Component descriptions

Optical path: The optical path and detector combination must be configured for a single dominant reflection with an optical return loss as specified in e.g. Table 60–5. (The optical return loss may be determined by the method of FOTP-107.)

The length of the fiber is not critical but should be in excess of 2 m.

Polarization rotator: The polarization rotator is capable of transforming an arbitrary orientation elliptically polarized wave into a fixed orientation linearly polarized wave.

O/E converter (and amplifier): If necessary, the noise may be amplified to a level consistent with accurate measurement by the power meter.

Filter: The upper -3 dB limit of the measurement apparatus is as specified for the transmitter optical waveform test. The bandwidth used in the RIN calculation takes the low-frequency cutoff of the DC blocking capacitor into consideration. The low-frequency cutoff is recommended to be less than 1 MHz.

The filter should be placed in the circuit as the last component before the power meter so that any high-frequency noise components generated by the detector/amplifier are eliminated. If the power meter used has a very wide bandwidth, care should be taken to ensure that the filter does not lose its rejection at extremely high frequencies.

Power meter: The RMS electrical power meter should be capable of being zeroed in the absence of input optical power to remove any residual noise.

60.8.7.3 Test procedure

Use the following procedure to test relative intensity noise optical modulation amplitude:

a) With the DUT disconnected, zero the power meter;
b) Connect the DUT, turn on the laser, and ensure that the laser is not modulated;
c) Operate the polarization rotator while observing the power meter output to maximize the noise read by the power meter. Note the maximum power, P_N;
d) Turn on the modulation to the laser using the pattern specified for the PMD type and note the power measurement, P_M. It may be necessary to change or remove the effective reflection to obtain an accurate reading;
e) Calculate RIN from the observed electrical signal power and noise power by use of the equation:

$$RIN_xOMA = 10\log\frac{P_N}{BW \times P_M} \quad [\mathrm{dB/Hz}] \tag{60-7}$$

Where:
RIN_xOMA = Relative Intensity Noise referred to optical modulation amplitude measured with x dB reflection,
P_N = Electrical noise power in Watts with modulation off,
P_M = Electrical power in Watts with modulation on,
BW = Low pass bandwidth of apparatus - high pass bandwidth of apparatus due to DC blocking capacitor [noise bandwidth of the measuring system (Hz)].

For testing multimode components or systems, the polarization rotator is removed from the setup and the single mode fiber replaced with a multimode fiber. Step c) of the test procedure is eliminated.

60.8.8 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 60–6. Compliance is to be assured during system operation. Measurements shall be performed using the test pattern defined in 60.8.1.

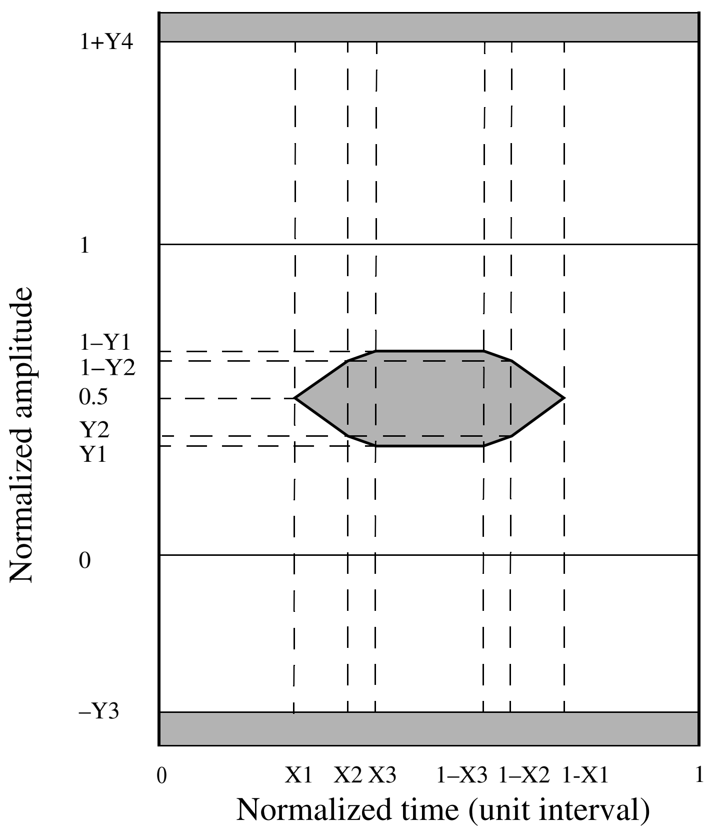

Figure 60–5—Transmitter eye mask definition

Normalized amplitudes of 0 and 1 represent the amplitudes of logic ZERO and ONE respectively. 0 and 1 on the unit interval scale are to be determined by the eye crossing means. A clock recovery unit (CRU) may be used to trigger the scope for mask measurements as shown in Figure 60–6. It should have a high frequency corner bandwidth of less than or equal to 20 kHz and a slope of -20 dB/decade. The frequency response of the measurement instrument (e.g. oscilloscope) extends substantially lower than the test pattern repetition frequency. A DC coupled instrument is convenient.

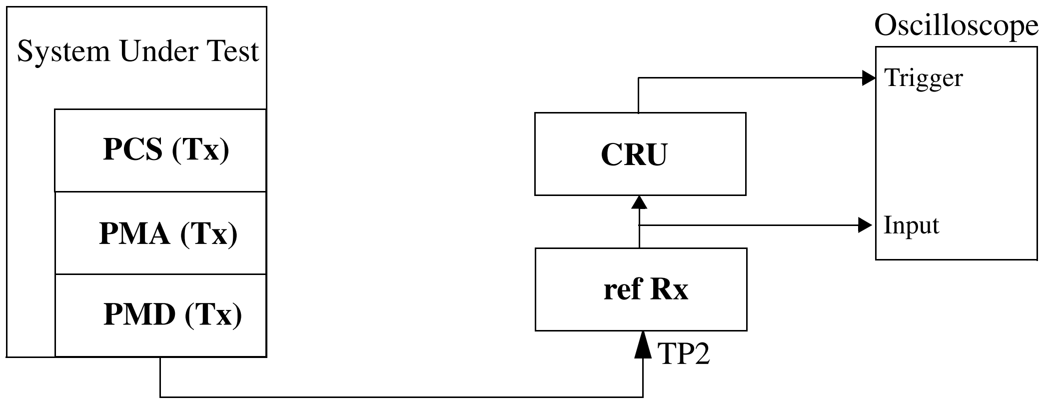

Figure 60–6—Transmitter optical waveform test block diagram

The eye shall be measured with respect to the mask of the eye using a receiver with a fourth-order Bessel-Thomson response with nominal *fr* of 116.64 MHz as specified for STM-1 in ITU-T G.957, with the tolerances there specified.

This Bessel-Thomson receiver is not intended to represent the noise filter used within a compliant optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

> ***Editors' Note:*** *To be removed prior to final publication.*
> Further study is required to assure that the eye mask is appropriate for all forms of clock recovery.

60.8.9 Transmitter and dispersion penalty measurement

The transmitter and dispersion penalty (TDP) measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single mode fiber, and for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g. eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The procedure tests for pattern dependent effects; for 100BASE-LX10 and 100BASE-BX10, a standardized element of pattern dependent baseline wander is included in the reference channel.

Transmitter and dispersion penalty may be measured with apparatus shown in Figure 60–7, consisting of a reference transmitter, the transmitter under test, a controlled optical reflection, an optical attenuator, a test fiber, and a reference receiver system containing a reference receiver front end (optical to electrical converter), a transversal filter to emulate multimode fiber, if appropriate, and a bit-error rate tester. All BER and sensitivity measurements are made with the test patterns specified for the PMD type, e.g. in 60.8.1.

NOTE— This TDP measurement procedure applies to Clauses 58*ref*, 59*ref* and 60*ref*.

NOTE— Multimode fiber is not used with 100BASE-LX10 or 100BASE-BX10.

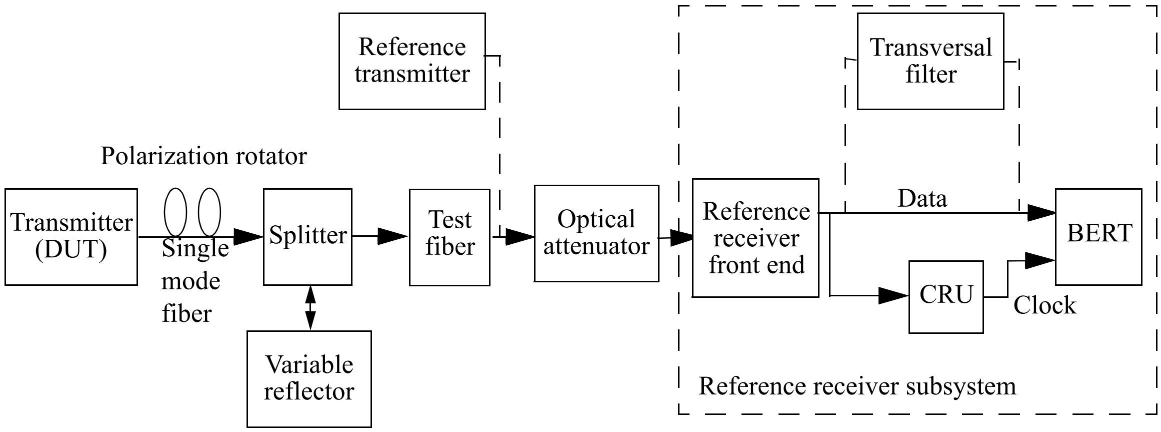

Figure 60–7—Test setup for measurement of transmitter and dispersion penalty

60.8.9.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should meet the following basic requirements:

a) The rise/fall times should be less than 0.15 UI at 20% to 80%.
b) The output optical eye is symmetric and with good margin to the eye mask test for the transmitter (PMD) type under test.
c) In the center 20% region of the eye, the worst-case vertical eye closure penalty, as defined in 60.8.11.2, is less than 0.5 dB.
d) Jitter less than 0.20 UI peak-peak.
e) $RIN_{12}OMA$ should be minimized to less than -120 dB/Hz for 100BASE-X and -125 dB/Hz for 1000BASE-X.

60.8.9.2 Channel requirements

The transmitter is tested using an optical and electrical channel that meets the requirements specified for the PMD type listed in Table 60–12.

Table 60–12—Transmitter compliance channel specifications

PMD transmitter wavelength, fiber type	Optical channel			Electrical channel
	Dispersion[a] (ps/nm)		Optical return loss[b] (max)	Differential delay (ps)
	Minimum	Maximum		
1310 nm band for SMF	$0.02325 \cdot L^{c} \cdot \lambda \cdot [1-(1324/\lambda)^4]$	$0.02325 \cdot L \cdot \lambda \cdot [1-(1300/\lambda)^4]$	See ORLT in Transmitter spec	N/A
1550 nm band for SMF	0	$0.02325 \cdot L \cdot \lambda \cdot [1-(1300/\lambda)^4]$		N/A

[a]The dispersion is specified for the actual wavelength of the device under test.
[b]The optical return loss is applied with respect to TP2.
[c]L is the upper operating range limit (reach) as defined e.g. in Table 60–1.

A transmitter is to be compliant with a total dispersion at least as negative as the “minimum dispersion” and at least as positive as the “maximum dispersion” columns specified for the wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in ANSI/TIA/EIA-455-175A-92 may be used. The measurement is made in the linear power regime of the fiber.

When emulating a multimode fiber link, the optical channel is a 2 to 5 m patch cord meeting the appropriate specifications. In this case, the link bandwidth is emulated in the electrical domain.

The channel provides a maximum optical return loss specified as “Optical return loss tolerance (max)” in the specification of the transmitter under test. The state of polarization of the back reflection is adjusted to create the greatest RIN. The methods of 60.8.7.2 and 60.8.7.3 may be used.

The optical attenuation is minimized; there is no intent to stress the sensitivity of the BERT's optical receiver.

60.8.9.3 Reference receiver requirements

The reference receiver system should have the bandwidth specified for the transmitter optical waveform measurement for the transmitter under test. The sensitivity of the reference receiver system should be limited by Gaussian noise. The receiver system should have minimal threshold offset, deadband, hysteresis, deterministic jitter or other distortions. Decision sampling should be instantaneous with minimal uncertainty and setup/hold properties. When testing 100BASE-X optical transmitters, the receiver should have a passband not extending below 10 kHz at the -3 dBe (electrical) point, so as to emulate the pattern-induced baseline wander expected in a compliant receiver.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. Center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BER is greater than or equal to 10^{-3}. The decision threshold is to occur at the average signal level.

For a transmitter to be used with multimode fiber the reference receiver is followed by a transversal filter with two equal amplitude paths with a differential delay as specified for the transmitter. In this case, the receiver front end should be operating in its linear regime (not clipping). For a transmitter to be used with single mode fiber, the transversal filter is not used.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of less than or equal to the jitter tolerance frequency specified for the appropriate receiver (the peer PMD to the transmitter under test), and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

The nominal sensitivity of the reference receiver system, S, is measured in OMA using the apparatus described above but with a short patchcord in place of the test fiber and without any transversal filter. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It should be measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test.

60.8.9.4 Test procedure

To measure the transmitter and dispersion penalty (TDP) the following procedure shall be used. The sampling instant is displaced from the eye center by the amount specified in e.g. 60.7. The following procedure is repeated for early and late decision and the larger TDP value is used:

a) Configure the test equipment as described above and illustrated in Figure 60–7.
b) Adjust the attenuation of the optical attenuator to obtain a BER of 10^{-12}. Extrapolation techniques may be used with care.
c) Record the optical power in OMA at the input to the reference receiver, P_DUT, in dBm.
d) If P_DUT is larger than S, the transmitter and dispersion penalty (TDP) for the transmitter under test is the difference between P_DUT and S, TDP = P_DUT - S. Otherwise the transmitter and dispersion penalty is zero, TDP = 0.

It is to be ensured that the measurements are made in the linear power regime of the fiber.

60.8.9.5 Approximate measures of TDP (informative)

The following suggestions apply to 100 Mb/s optical PMDs.

In practice it may be necessary to do without the clock recovery unit at 100 Mb/s. Experimentally, timing stability at this rate may be acceptable, and the jitter due to the CRU could be accounted for by adjusting the eye mask length and the TDP decision timing offsets.

A significant component of TDP is baseline wander. A wander of ± OMA/10 will be created by many receivers if it is not already present in the transmitted signal. Higher levels of pattern dependent penalty can in some cases be estimated from the mask margin (if necessary, by ignoring the upper and lower mask regions). The mask margin may also be measured with an AC coupled measurement instrument with a high pass filter of 10 kHz. It is likely that compliant implementations will pass the transmitter mask with both DC and AC coupling. Certain implementations may be characterized by comparing the transmitted signal with the STM-1 mask, using a benign pattern such as PRBS7.

The accuracy of these approaches have not been established by the committee. Oscilloscope measurements at TP3 may be degraded by instrument noise.

60.8.10 Receiver sensitivity measurements

Receiver sensitivity is defined for an ideal input signal. The test signal should have negligible impairments such as intersymbol interference (ISI), jitter and RIN (but see the end of this subclause). The test pattern is specified in e.g. 60.8.1. Sensitivity is defined by the specified bit error rate, which may be determined by counting bit or byte errors or errored frames. Extrapolation techniques may be used with care. Sensitivity is measured at a low but compliant extinction ratio, and correction made for any difference between the measurement extinction ratio and the specified minimum extinction ratio. This assurance should be met with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is the same pattern as defined for this measurement.

The sampling point is set by the system under test. While this standard applies to complete data terminal equipment (DTE), the test may be used as a diagnostic for testing components with appropriate margin, in which case the sampling point should be set at the average optical power level and at the specified timing offsets from the eye center, which may be found as the mid-point between the 10^{-3} BER points.

In the case of 100BASE-X, systematic baseline wander of the input signal is to be expected. This may be generated with AC coupling above 10 kHz within the transmitter, and/or with the interfering signal technique as described in 60.8.11.2. A standardized baseline wander of ± OMA/10 is defined for these PMD types. This causes some jitter in the test signal, which is acceptable.

NOTE— This receiver sensitivity measurement applies to Clauses 58*ref*, 59*ref* and 60*ref*.

60.8.11 Stressed receiver conformance test (informative)

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. Stressed receiver tolerance testing may be performed in accordance with the requirements of 60.8.11.1, 60.8.11.2, and 60.8.11.3

A receiver should receive a conditioned input signal that combines vertical eye closure and jitter according to this clause with BER less than 10^{-12}. This assurance should be met with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern as defined for this measurement.

> ***Editors' Note:*** *To be removed prior to final publication.*
> This is a poor choice for 100M. An asynchronous pattern would be better, if it matters.

NOTE— This stressed receiver conformance test applies to Clauses 58*ref*, 59*ref* and 60*ref*.

60.8.11.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 60–8. A pattern generator continuously generates a signal or test pattern as specified for the receiver under test, e.g. in 60.8.1. The optical test signal is conditioned (stressed) using the methodology, as defined in 60.8.11.2, while applying sinusoidal jitter, as specified e.g. in 60.8.11.4. The receiver of the system under test is tested for conformance by counting bit or byte errors or errored frames. The optical power penalty for the stressed eye is intended to be similar to its vertical eye closure penalty. This is not necessarily the same as the highest TDP anticipated in service, but represents a standardized test condition for the receiver.

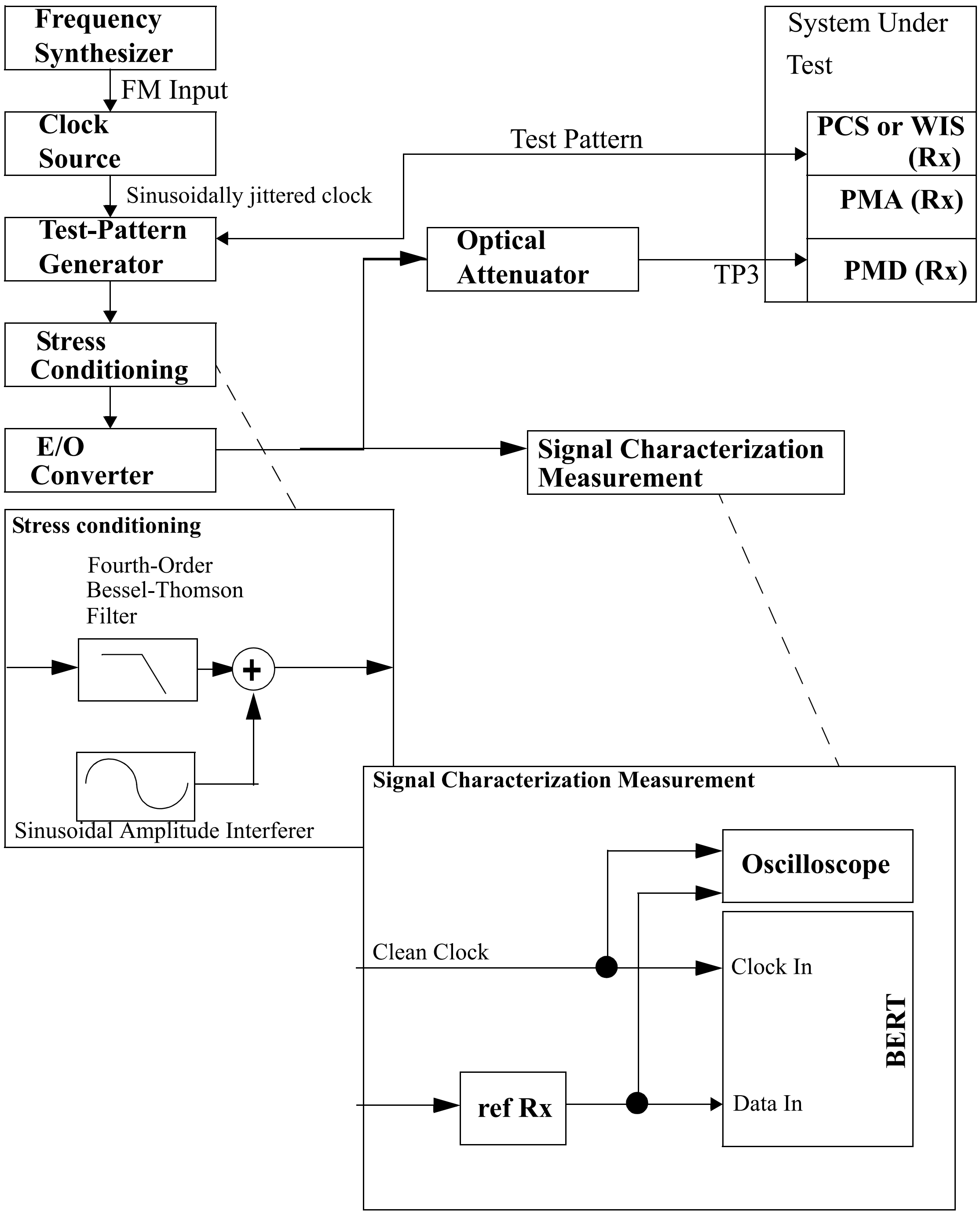

Figure 60–8—Stressed receiver conformance test block diagram

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. The test fiber called out for single mode fiber based PMD layers and the transversal filter called out to emulate multimode fiber are not needed to characterize the receiver input signal; nor are they used during testing.

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure. The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter. The nature of the jitter is intended to emulate instantaneous bit shrinkage that can occur with DDJ. This type of jitter cannot be created by simple phase modulation. The sinusoidal phase modulation represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter.

For improved visibility for calibration, it is imperative that the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) have wide and smooth frequency response and linear phase response throughout the spectrum of interest. Overshoot and undershoot should be minimized. If this is achieved, then data dependent effects should be minimal, and short data patterns can be used for calibration with the benefit of providing much improved trace visibility on sampling oscilloscopes. Actual patterns for testing the receiver are specified in the appropriate clause.

To further improve visibility for calibration, random noise effects, such as RIN and random clock jitter, should also be minimized. A small amount of residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak of jitter.

The test pattern generator, filter and E/O converter should together have a frequency response to result in the appropriate level of initial ISI eye closure before the sinusoidal terms are added. The E/O converter should have a linear response if electrical summing is used, linearity of all elements including the E/O modulator is critical. Summing with an optical coupler after the modulator is an option that eases linearity requirements, but requires a second source for the interfering signal, will complicate settings of extinction ratio, and will add more RIN. In either case, a typical optical transmitter with built-in driver is not linear and not suitable.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using an optical reference receiver with the response specified for the appropriate transmitter (the peer PMD to the receiver under test) e.g. in 60.8.8. Use of standard tolerance filters may significantly degrade this calibration. Care should be taken to ensure that all the light from the fiber is collected by the fast photo detector and that there is negligible mode selective loss, especially in the optical attenuator and the optical coupler, if used. The reference receiver and oscilloscope should achieve adequately low noise and jitter.

The clock output from the clock source in Figure 60–8 will be modulated with the sinusoidal jitter. To use an oscilloscope to calibrate the final stressed eye jitter that includes the sinusoidal jitter component, a separate clock source (clean clock of Figure 60–8) is required that is synchronized to the source clock, but not modulated with the jitter source.

60.8.11.2 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver meets BER requirements with near worst case waveforms at TP3 including pulse width shrinkage, power, simulated channel penalties, and a swept frequency sinusoidal jitter contribution.

Signal characteristics are described below along with a suggested approach for calibration.

The test signal includes vertical eye closure and high-probability jitter components. Vertical eye closure is measured at the time center of the eye (halfway between 0 and 1 on the unit interval scale as determined by the eye crossing means) and is the vertical eye closure penalty (VECP) when calculated relative to the measured A_N value. J is measured at the average optical power, which can be obtained with AC coupling. The values of these components are defined as below by their histogram results. The vertical eye closure penalty is given by the equation:

$$\text{Vertical eye closure penalty [dB, optical]} = 10 \times \log\frac{A_N}{A_O} \tag{60-8}$$

where, A_O is the amplitude of the eye opening and A_N is the normal amplitude without ISI, as shown in Figure 60–9. A_N can be approximated with histograms as suggested in Figure 60–9. However, the normative definition for A_N is given in 60.8.5.

For this test, VECP is defined by the 99.9th [99.95th?] percentile of the histogram of the lower half of the signal and the 0.1th [0.05th?] percentile of the histogram of the upper half of the signal, and jitter is defined by the 1st and 99th percentiles of the jitter histogram. Histograms should include at least 10 000 hits, and should be about 1%-width in the direction not being measured. Residual low-probability noise and jitter should be minimized -that is, the outer slopes of the final histograms should be as steep as possible down to very low probabilities.

The following steps describe a suggested method for calibrating a stressed eye generator:

1) Set the signalling speed of the test-pattern generator as specified for the appropriate transmitter. Sinusoidal interference and jitter signals should be turned off at this point.

2) Turn on the calibration pattern. A repetitive pattern may be used for calibration if the conditions described in 60.8.11.1 are met, but this increases the risk that the longer test pattern used during testing will overstress the device under test.

3) Set the extinction ratio to approximately the extinction ratio (min) value as specified for the appropriate transmitter. If optical summing is used, the extinction ratio may need to be adjusted after the sinusoidal interference signal is added below.

4) Measure the settled signal amplitude A_N of the test signal (without attenuation). A_N may be measured according to 60.8.5 using a square wave pattern, although for the purposes of this clause, OMA is to be measured with a different pattern; A_N and OMA are not likely to be equal.

5) The requirements for vertical eye closure and jitter of the stressed eye test signal are given by the vertical eye closure penalty (VECP) and stressed eye jitter (J) values given in the appropriate receiver specification table.

   There are three components involved in calibration for vertical closure and J. These are a linear phase filter, sinusoidal interference, and sinusoidal jitter.

   Without sinusoidal jitter or sinusoidal interference, the majority of the vertical eye closure penalty value should be created by use of a linear phase, low jitter filter (such as Bessel-Thomson). The filter should be tested with the prescribed test patterns to verify that residual jitter is small, less than 0.25 UI peak-peak. If not, the stress may be more than desired, leading to conservative results. However, compensation is not allowed. Once done, revert to the calibration pattern, if different than the specified test pattern.

   Any remaining vertical eye closure required must be created with sinusoidal interference or sinusoidal jitter.

   To emulate the effects of DCD or data-dependent jitter, at least 0.05 but no more than 0.15 UI peak-peak of pulse shrinkage jitter should have been achieved. This imposes a limit of less than 1.2 dB of vertical closure from sinusoidal interference, applied after vertical closure created by filtering.

> ***Editors' Note:*** *To be removed prior to final publication.*
> This spec may be PMD specific too.

The frequency of the sinusoidal interference may be set at any frequency between B / 100 and B / 5 where B is the signalling speed, although be careful to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the signalling speed and the pattern repetition rate.

Sinusoidal jitter (phase modulation) must be added according to the appropriate jitter specification. For calibration purposes, sinusoidal jitter frequencies must be well within the flat portion of the template above the corner frequency.

Iterate the filter bandwidth and the settings for sinusoidal interference and/or jitter until all constraints are met, including jitter (J), vertical closure (VECP), and that sinusoidal jitter above the corner frequency is as specified.

Verify that the optical power penalty for the stressed eye (relative to the reference transmitter per 60.8.9.1) is greater than or equal to VECP.

6) Decrease the amplitude with the optical attenuator until the OMA complies with the OMA values specified for the receiver under test.
7) For testing, turn on the actual required test pattern(s).

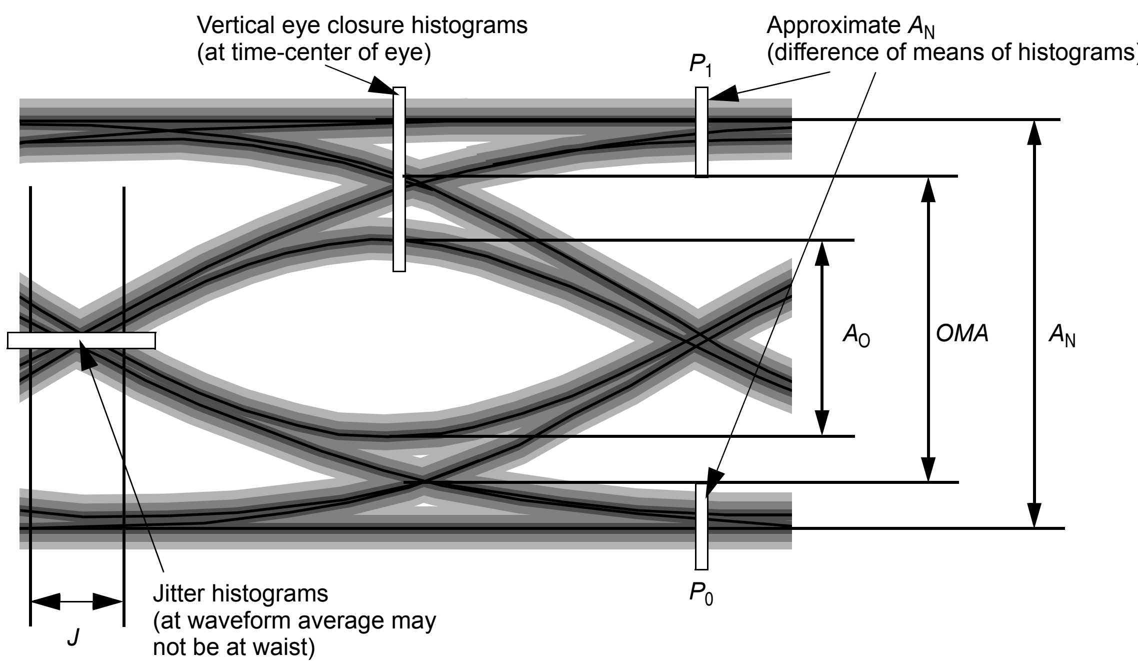

Figure 60–9—Required characteristics of the conformance test signal at TP3

Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative impact on yield but will not effect interoperability. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant receivers. Care should be taken to minimize and/or correct for the noise/jitter introduced by the reference receiver, filters, oscilloscope, and BERT. While the details of measurement and test equipment are beyond the scope of this standard it is recommended that the implementers fully characterize their test equipment and apply appropriate guard bands to ensure that the receive input signal meets the specified requirements.

60.8.11.3 Stressed receiver conformance test procedure

The test apparatus is set up as described in 60.8.11.1 and 60.8.11.2. The sinusoidal jitter is then stepped across the specified frequency and amplitude range while monitoring BER at the receiver. The BER is to be compliant at all jitter frequencies in the specified frequency range. This method does not result in values for jitter contributed by the receiver. It does, however, ensure that a receiver meeting the requirements of this test will operate with the worst-case optical input.

60.8.11.4 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. Sinusoidal jitter may vary over a magnitude range as required to accurately calibrate a stressed eye per 60.8.11.2. The range is limited by the constraints of Table 60–13 as illustrated in Figure 60–10, where f2, SJ1 and SJ2 are specified in the appropriate receiver table, e.g. Table 60–6 or Table 60–8.

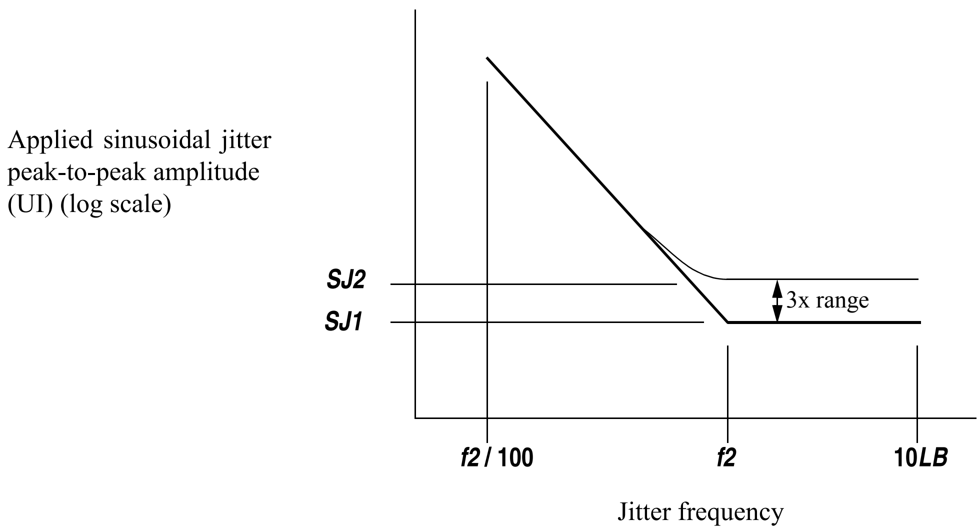

Figure 60–10—Mask of the sinusoidal component of jitter tolerance (informative)

Table 60–13—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter (UI $_{pk\ to\ pk}$)
$f < f2 / 100$	N/A
$f2 / 100 < f \le f2$	$0.05 \times f2 / f + S - 0.05$[a]
$f2 < f < 10 \times LB$[b]	$SJ1 \le S \le SJ2$[a]

[a] *S* is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 60.8.11.2.
[b] *LB* = Loop Bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

60.8.12 Jitter measurements (informative)

A jitter measurement method for use at 100 or 1000 Mb/s is described in this subclause. The measurement is performed after any relevant fiber dispersion (at virtual TP3).

The transmit jitter is tested using a bit error ratio tester (BERT), where the tester scans the eye opening horizontally (varying the decision time) at the average optical power, at a virtual TP3 (hereafter referred to as simply TP3) and measures the bit error ratio at each point in time. The plot of BER as a function of sampling time is called the "bathtub curve." The channel and receiver are as specified in e.g. 60.10.2 and 60.10.3. The test pattern is the same as for receiver sensitivity measurements.

> ***Editors' Note:*** *To be removed prior to final publication.*
> Test patterns for 100 Mb/s are specified in this clause. For 1000 Mb/s, CJPAT in Annex 48A.5 or maybe CRPAT in 48A.4 or 36A. Delete this note when Cl.58,59 patterns for sensitivity testing are specified (may be there already).

NOTE— The parameter W may also be estimated from jitter histograms using an oscilloscope. Jitter of an optical signal is measured with a test optical receiver with the receiver bandwidth specified (e.g. for eye mask conformance) for the transmitter under test concerned.

The experimental curve is compared with a mask defined by the following equations and illustrated in Figure 60–11:

$$\log_{10}(BER) \le A - B\left(\frac{t - 0.5W}{\sigma}\right)^2 \quad (60\text{-}9)$$

$$\log_{10}(BER) \le A - B\left(\frac{1 - t - 0.5W}{\sigma}\right)^2 \quad (60\text{-}10)$$

where:

$$A = -1.75,\ B = \frac{\log_{10}(e)}{2} \approx 0.217$$

and "t" is the decision time specified in unit intervals (UI).

The BER mask is defined for $10^{-12} < \text{BER} < 10^{-6}$. All points on the BER "bathtub curve" must fall within the white area or below. It can be seen that in the case of an asymmetric measured bathtub curve, the worse side determines W and σ.

W (“high probability jitter”) and deterministic jitter (DJ) are not necessarily the same, but may be similar. The quantity σ can be similar to random jitter (RJ) although it is determined by low probability pattern dependent jitter also. “Total jitter” (TJ) is taken to be W + 14σ.

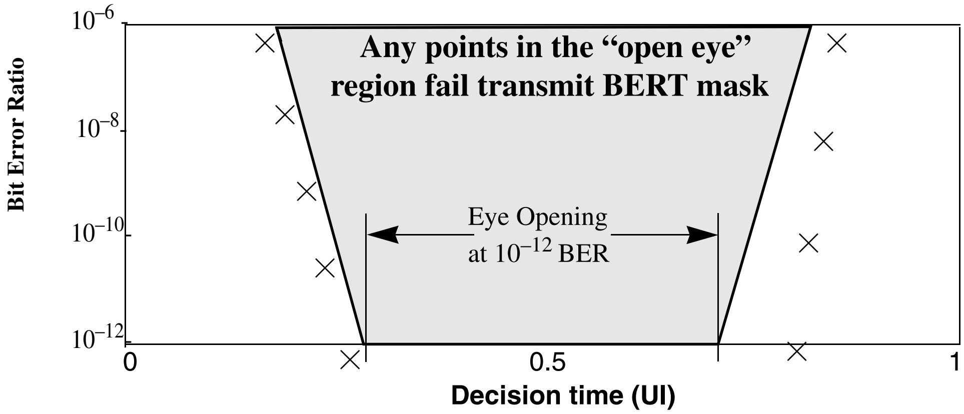

Figure 60–11—Example transmit BER mask at TP3

NOTE— This jitter measurement method applies to Clauses 58*ref*, 59*ref* and 60*ref*.

60.9 Environmental, safety and labeling

60.9.1 General safety

All equipment meeting this standard shall conform to IEC 60950.

60.9.2 Laser safety

100BASE-LX10 and 100BASE-BX10 optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825-1, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographical regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product’s laser, safety features, labeling, use, maintenance and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

60.9.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

60.9.4 Environment

Reference *ref* Annex 66A for additional environmental information.

60.9.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 100BASE-BX10-U).

Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 60.9.2.

Compliant systems and field pluggable components shall be clearly labeled with the operating temperature range over which their compliance is ensured.

60.10 Characteristics of the fiber optic cabling

The 100BASE-LX10 and 100BASE-BX10 fiber optic cabling shall meet the dispersion specifications of IEC 60793-2 and ITU G.652, as shown in Table 60–14. The fiber cable attenuation is for information only; the end-to-end channel loss shall meet the requirements of Table 60–1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 60–12.

60.10.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 60–12.

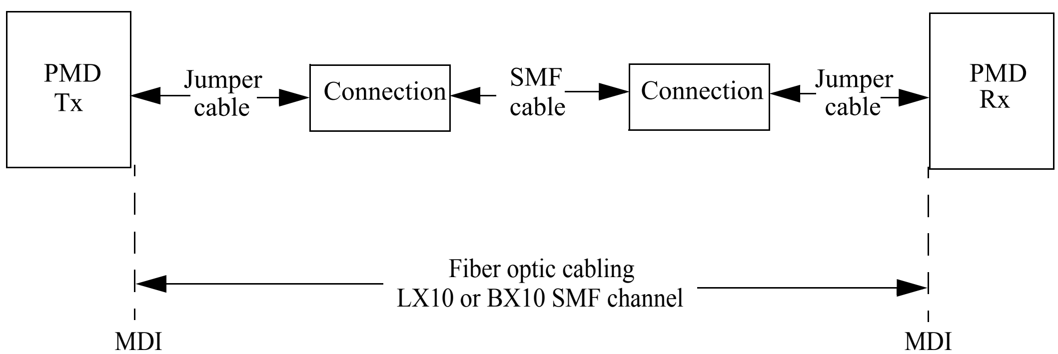

Figure 60–12—Fiber optic cabling model

The maximum channel insertion losses shall meet the requirements specified in Table 60–1. The minimum loss for 100BASE-LX10 and 100BASE-BX10 is zero. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion and reflections, meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7 [B15], method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

60.10.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2, Types B1.1 (dispersion un-shifted single mode) and B1.3 (low water peak single mode) and ITU G.652 as noted in Table 60–14.

60.10.3 Optical fiber connection

The maximum link distances for single-mode fiber are calculated based on an allocation of 2 dB total connection and spice loss. Connections with different loss characteristics may be used provided the requirements of Table 60–1 are met.

The maximum discrete reflectance of e.g. a connection or splice shall be less than -26 dB.

Table 60–14—Optical fiber and cable characteristics

Description[a]	B1.1, B1.3 SMF		Unit
Nominal fiber specification wavelength[b]	1310	1550	nm
Fiber cable attenuation (max)[c]	0.4	0.35	dB/km
Zero dispersion wavelength (λ_0)[d]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max) (S_0)	0.093		ps/nm^{2}km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Wavelength specified is the nominal fiber specification wavelength which is the typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation values are informative not normative. Attenuation for single-mode optical fiber cables is defined in ITU-T G.652.
[d]See IEC 60793 or G.652 for correct use of zero dispersion wavelength and dispersion slope.

60.10.4 Medium Dependent Interface (MDI)

The 100BASE-LX10, 100BASE-BX10-D or 100BASE-BX10-U PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” (as shown in Figure 60–12). Examples of an MDI include:

a) Connectorized fiber pigtail;
b) PMD receptacle.

When the MDI is a remateable connection it shall meet the interface performance specifications of IEC 61753-1-1, Fibre optic interconnecting devices and passive component performance standard - Part 1-1: General and guidance - Interconnecting devices (connectors).

NOTE—Compliance testing is performed at TP2 and TP3 as defined in Clause 60.3.1, not at the MDI.

60.11 Protocol Implementation Conformance Statement (PICS) proforma for Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 (Long Wavelength) and 100BASE-BX10 (BiDirectional Long Wavelength)

60.11.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3ah-2003, Clause 60*ref*, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10, shall complete the following Protocol Implementation Conformance Statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21*ref*.

60.11.2 Identification

60.11.2.1 Implementation identification

Supplier[1]	
Contact point for enquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTES 1—Required for all implementations. 2—May be completed as appropriate in meeting the requirements for the identification. 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

60.11.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3ah-2003, Clause 60*ref*, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21*ref*; the answer Yes means that the implementation does not conform to IEEE Std 802.3ah-2003.)	

Date of Statement	

60.11.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*MD	MDIO capability	60.2	Registers and interface supported	O	Yes [ ] No [ ]
HT	High temperature operation	60.1	XX to YY °C	O	Yes [ ] No [ ]
LT	Low temperature operation	60.1	WW to ZZ °C	O	Yes [ ] No [ ]
*LX	100BASE-LX10 PMD	60.4	Device supports long wave-length (1310 nm) operation	O/1	Yes [ ] No [ ]
*BX-D	100BASE-BX10-D	60.5	Device supports bidirectional long wavelength operation	O/1	Yes [ ] No [ ]
*BX-U	100BASE-BX10-U	60.5	Device supports bidirectional long wavelength operation	O/1	Yes [ ] No [ ]
*INS	Installation / Cable	60.10	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufac-turer	O	Yes [ ] No [ ]

Editors' Note: *To be removed prior to final publication.*
The temperature limit values of XX, YY, WW and ZZ in the above table are for discussion in the STF

60.11.3 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10

60.11.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Integration with 100BASE-X PCS and PMA	60.1		M	Yes [ ]
FN2	Transmit function	60.3.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN3	Transmitter optical signal	60.3.2	Higher optical power transmitted is a logic 1	M	Yes [ ]
FN4	Receive function	60.3.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN5	Receiver optical signal	60.3.3	Higher optical power received is a logic 1	M	Yes [ ]
FN6	Signal detect function	60.3.4	Mapping to PMD service interface	M	Yes [ ]
FN7	Signal detect behavior	60.3.4	Generated according to Table 60–4	M	Yes [ ]

60.11.3.2 PMD to MDI optical specifications for 100BASE-LX10

Item	Feature	Subclause	Value/Comment	Status	Support
LX1	100BASE-LX10 transmitter	60.4.1	Meets specifications in Table 60–5	LX:M	Yes [ ] N/A [ ]
LX2	100BASE-LX10 receiver	60.4.2	Meets specifications in Table 60–6	LX:M	Yes [ ] N/A [ ]

60.11.3.3 PMD to MDI optical specifications for 100BASE-BX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
BX-D1	100BASE-BX10 transmitter	60.5.1	Meets specifications in Table 60–7	BX-D:M	Yes [ ] N/A [ ]
BX-D2	100BASE-BX10 receiver	60.5.2	Meets specifications in Table 60–8	BX-D:M	Yes [ ] N/A [ ]

60.11.3.4 PMD to MDI optical specifications for 100BASE-BX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
BX-U1	100BASE-BX10 transmitter	60.5.1	Meets specifications in Table 60–7	BX-U:M	Yes [ ] N/A [ ]
BX-U2	100BASE-BX10 receiver	60.5.2	Meets specifications in Table 60–8	BX-U:M	Yes [ ] N/A [ ]

60.11.3.5 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable		2 to 5 meters in length	M	Yes [ ]
OM2	Test pattern	60.8.1, 60.8.8		M	Yes [ ]
OM3	Wavelength and spectral width measurement	60.8.2	Per TIA/EIA-455-127 under modulated conditions	M	Yes [ ]
OM4	Average optical power	60.8.3	Per TIA/EIA-455-95	M	Yes [ ]
OM5	Extinction ratio	60.8.4	Per ANSI/TIA/EIA-526-4A [B13]	M	Yes [ ]
OM6	Transmit eye	60.8.8	With specified filter	M	Yes [ ]
OM7	Receiver sensitivity	60.8.10	***this subclause needs a “shall”	M	Yes [ ]
OM8	Transmitter and dispersion penalty measurement	60.8.9	With dispersion, reflection and decision timing offsets	M	Yes [ ]
OM9	Stressed receiver conformance test	60.8.11	Performed in accordance with the requirements of 60.8.11.1, 60.8.11.2, and 60.8.11.3	M	Yes [ ]

60.11.3.6 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	60.9.1	Conforms to IEC-60950	M	Yes [ ]
ES2	Laser safety —IEC Class 1	60.9.2	Conform to Class 1 laser requirements defined in IEC 60825-1	M	Yes [ ]
ES3	Documentation	60.9.2	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labelling	60.9.5	If required	M	Yes [ ] N/A [ ]

60.11.3.7 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	60.10	Dispersion specifications of Table 60–14	INS:M	Yes [ ] N/A [ ]
FO2	End-to-end channel loss	60.1, 60.10	Meet the requirements of Table 60–1	INS:M	Yes [ ] N/A [ ]
FO3	Maximum discrete reflectance	60.10.3	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	60.10.4	IEC 61753-1-1 if rematable	INS:O	Yes [ ] N/A [ ]

61. Physical Coding Sublayer (PCS) and common specifications, type 10PASS-TS and type 2BASE-TL

Editors' Notes: *To be removed prior to final publication.*

References:

ITU-T G.993.1
ITU-T G.994.1

Definitions (to be added to 1.4):

None

Abbreviations (to be added to 1.5):

CO: Central Office
CPE: Customer Premises Equipment
EFM: Ethernet in the First Mile
PAF: PMI Aggregation Function
PAFH: PMI Aggregation Function Header

Revision History:

Draft 0.9	June 2002	Preliminary draft outline for IEEE P802.3ah Task Force review.
Draft 1.0	August 2002	Preliminary draft for IEEE P802.3ah Task Force review
Draft 1.1	October 2002	Draft for IEEE P802.3ah Task Force review
Draft 1.2	November 2002	Draft for IEEE P802.3ah Task Force review
Draft 1.3	January 2003	Draft for IEEE P802.3ah Task Force review
Draft 1.414	April 2003	Draft for IEEE P802.3ah Task Force review which incorporates resolved comments from March 2003 Plenary Meeting.

61.1 Overview

10PASS-TS and 2BASE-TL are Physical Layer signaling systems for Ethernet in the first mile. These PHYs deliver a minimum of 10 Mb/s over distances of up to 750 meters, and a minimum of 2Mb/s over distances of up to 2700 meters, using a single copper pair. Optionally, transmission over multiple copper pairs is supported.

The copper category of EFM PHYs is based on DSL PMDs used in the access network according to ATIS T1, ETSI and ITU-T standards. These systems are intended to be used in public as well as private networks; therefore they shall be capable of compliance with appropriate regulatory, governmental and regional requirements.

Unlike the media types specified for 10BASE-T, 100BASE-T and 1000BASE-T, voice-grade copper networks have channel characteristics that are very diverse and therefore it is conventional to discuss the channel behavior only in terms of averages, standard deviations and percentage worst case.

61.1.1 Scope

This clause defines the Physical Coding Sublayers (PCS) for 2BASE-TL and 10PASS-TS, which have similarities to other 802.3 standards such as 100BASE-T4 but also differ since new sublayers are added within the PCS sublayers to accommodate the operation of Ethernet over access network copper channels. This clause also defines the common startup and handshaking mechanism used by both PHYs.

61.1.2 Objectives

The following are the objectives for 2BASE-TL and 10PASS-TS:

a) To provide 100 Mb/s data rate at the MII.
b) To provide full duplex operation.
c) To provide for operating over unshielded voice grade twisted pair cable.
d) To provide a communication channel with a mean bit error rate at the PMA service interface of less than one in part in 10^7 with a noise margin of 6dB (10PASS-TS) or 5dB (2BASE-TL).
e) To provide optional support for operation on multiple pairs
f) To provide functional layering in the PCS which ensures compatibility with the layering and frame interfaces for xDSL systems, including a γ-interface based on that used for the PTM-TC sublayer as defined in ITU-T Recommendation G.993.1.

61.1.3 Relation of 2BASE-TL and 10PASS-TS to other standards

The relation of 2BASE-TL and 10PASS-TS to other standards is shown schematically in Figure 61–1.

61.1.4 Summary

61.1.4.1 Summary of Physical Coding Sublayer (PCS) specification

Editor's Note: This section contains ew text in DSQRT(2) based on resolution of comments #523/D1.3, #748/D1.3, #894/D1.3, #895/D1.3 and #799/D1.3.

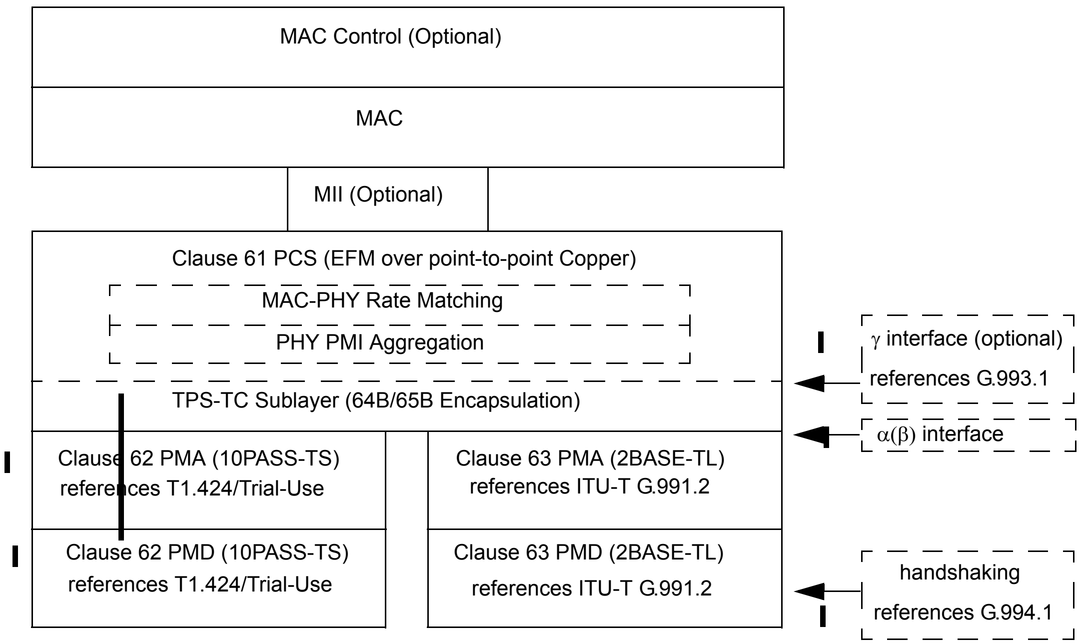

Figure 61–1—Relation of this clause to other standards

The Physical Coding Sublayers (PCS) for 2BASE-TL and 10PASS-TS contains two functions (MAC-PHY rate adaptation and PMI aggregation) and one subsection (the TPS-TC sublayer). The relationship between the functions and subsection is shown in Figure 61–2

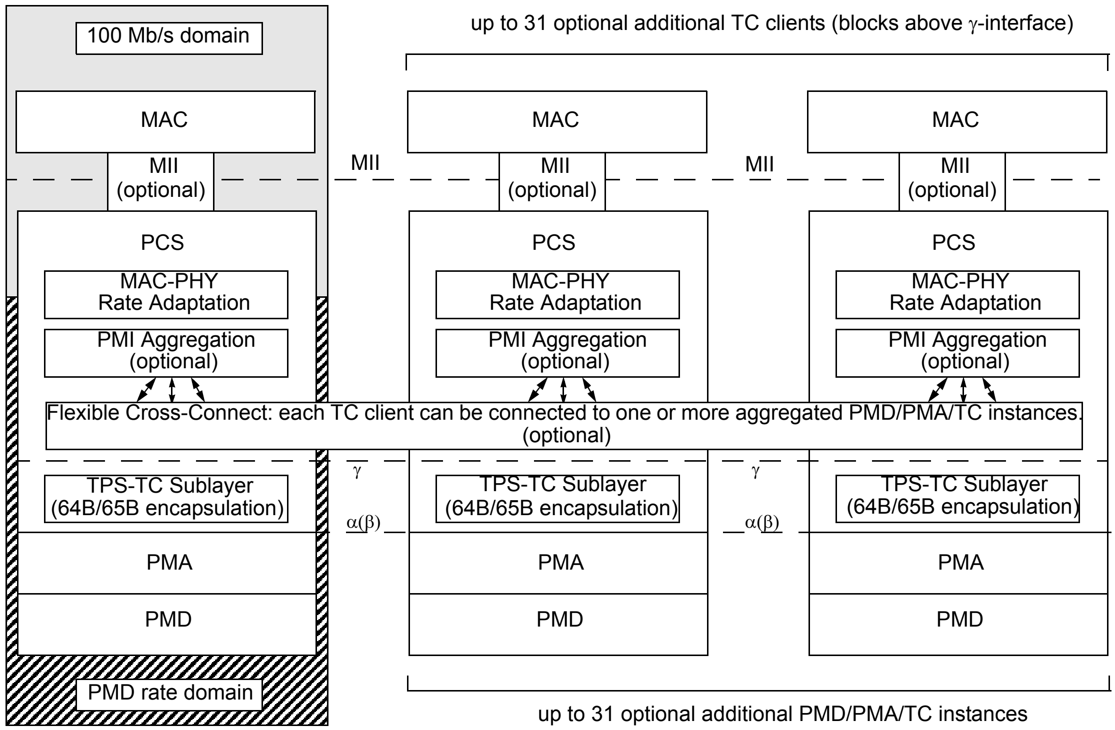

Figure 61–2—Overview of Physical Coding Sublayer functions

The γ-interface and α(β)-interface are specified in 61.2.3.1 and 61.2.3.2, respectively. They are generic interfaces used in various xDSL specifications, such as the ones referenced in Clause 62 and Clause 63. The α(β)-interface is a simple byte-synchronous data-interface; the γ-interface adds protocol-awareness (in the case of the TPS-TC defined in this Clause, the γ-interface can signal packet boundaries).

Note that clocks used in the shaded area labeled “PMD rate domain” may be derived from and synchronized to the DSL clocks which will be related to the bit rates. Data is transferred across the γ-interface at the speed of the lower layers. The clocks in the in the shaded area labeled “100 Mb/s domain” are synchronized to the MII clock. Data is transferred across the MII interface at the speed of the MII clock. The MAC-PHY rate matching function adjusts the inter packet gap so that the net data rate across these interface matches the sum of rates across the γ-interfaces.

In the transmit direction, frames are transferred from the MAC to the PCS across the MII interface when the MAC-PHY rate matching function allows this. In the PCS, preamble and SFD bytes are removed. If the optional PMI aggregation function (PAF) is present, the packet is fragmented by the PAF, and fragments are forwarded, optionally through a flexible cross-connect, towards each of the aggregated PMD/PMA/TC instances via their γ-interfaces. If the PAF is not present, the packet is forwarded to the TPS-TC sublayer via the γ-interface. The TPS-TC sublayer accepts data from the MAC-PHY rate matching function or the PAF, at the rate at which it can be process by the TPS-TC sublayer, by asserting Tx_Enbl on the γ-interface.

In the receive direction the TPS-TC sublayer pushes data to the PAF (if present) or the MAC-PHY rate matching function by asserting Rx_Enbl on the γ-interface. In multiple links are aggregated, the PAF reassembles the received fragments into packets. The preamble and SFD bytes are regenerated and prepended to the packet, prior to passing it up to the MAC across the MII interface. The MAC-PHY Rate Matching function may delay the transfer of the frame to avoid simultaneous transfer of Transmit and Receive frames if required.

61.1.4.1.1 Summary of MAC-PHY Rate Matching specification

The Ethernet in the first mile Physical Layer devices that operate over copper media are specified to work with a MAC operating at 100Mb/s using the MII interface as defined in Clause 22 [see Clause 22]. A function is needed to match the MAC's rate of data transmission to the PHY's slower data rate.

This is achieved using deference as defined in 4.2.3.2.1 [see Clause 4]. For deference to operate the MAC is configured for half duplex operation. It is important to note that Clause 4 [see Clause 4] does not prohibit the MAC from simultaneously receiving and transmitting data when configured for half duplex operation.

In response to the assertion of TX_EN by the MAC the PHY asserts CRS in response (see 4.3.3). The MAC transmits data at a rate of 100Mb/s, which is buffered by the PHY and transmitted onto the medium. In order to prevent the PHY's transmit buffer from overflowing the PHY keeps CRS asserted until it has space to receive a maximum length frame (i.e. maxUntaggedFrameSize + qTagPrefixSize, currently 1522 bytes (see 3.5, 4.2.7.1 and 4.4)). In half duplex mode the MAC will not transmit another frame as long as CRS is asserted.

The transmitter MAC-PHY Rate Maching function strips the Preamble and SFD fields from the MAC frame, and forwards the resulting data frame to the PMI Aggregation Function.

The PHY buffers complete receive frames. On reception of a complete frame the PHY prepends the Preamble and SFD fields, and sends it to the MAC at 100Mb/s.

It is recognized that some MAC implementations may not allow the simultaneous transmission and reception of data while operating in half duplex mode. To permit operation with these MACs the PHY has an operating mode where MAC data transmission is deferred using CRS when received data is sent from the PHY to the MAC. This mode of operation is defined in Figure 61–8 which describes the MAC-PHY rate matching receive state machine. This state machine gives receive frames priority over transmitted frames to ensure the receive buffer does not overflow.

The definition of MAC-PHY rate matching is presented in subclause 61.2.1.

61.1.4.1.2 Summary of PHY PMI Aggregation specification

An optional PHY PMI Aggregation Function (PAF) allows one or more PHYs to be combined together to form a single logical Ethernet link. The PAF is located between the MAC-PHY Rate Matching function and the TPS-TC functions. It interfaces with the PHYs across the γ-interface, and to the MAC-PHY Rate Matching function using an abstract interface. The definition of the PAF is presented in subclause 61.2.2

61.1.4.1.3 Summary of TPS-TC specification

Transport Protocol Specific Transmission Convergence Sublayer (TPS-TC) resides between the γ-interface of the PCS and alpha/beta-interface of the PMA. It is intended to convert the data frame to be sent into the format suitable to be mapped into PMA, and to recognize the received frame at the other end of the link. Since PMA and MII clocks may be unequal, the TPS-TC also provides clock rate matching. The definition of the TPS-TC sublayer is presented in subclause 61.2.3.

61.1.4.1.4 Overview of management

Ethernet OAM (see Clause 57) runs over an aggregated set of PMIs in a PMD. The Ethernet OAM operates as long as there is at last one PMI in the PMD that is operational. The physical xDSL PMIs in Clauses 62 and 63 each have their own management channel that operates per loop (EoC/voc/IB). The PMI OAM is used for loop activation, aggregation, and maintenance of an individual loop. Ethernet OAM is used to monitor and maintain the aggregate.

61.1.4.2 Summary of handshaking and PHY control specification

Both 2BASE-TL and 10PASS-TS use handshake procedures defined in ITU-T G.994.1 at startup. Devices implementing both 2BASE-TL and 10PASS-TS port types may use G.994.1 to determine a common mode of operation.

61.1.5 Application of 2BASE-TL, 10PASS-TS

61.1.5.1 Compatibility considerations

The PCS, PMA, and the MDI are defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the PCS and PMA in an application-dependent manner provided the MDI and MII specifications are met.

61.1.5.2 Incorporating the 2BASE-TL, 10PASS-TS PHY into a DTE

When the PHY is incorporated within the physical bounds of a DTE, conformance to the MII is optional, provided that the observable behavior of the resulting system is identical to that of a system with a full MII implementation. For example, an integrated PHY may incorporate an interface between PCS and MAC that is logically equivalent to the MII, but does not have the full output current drive capability called for in the MII specification.

61.1.5.3 Use of PHY Rate Matching

61.1.5.4 Application and examples of PHY PMI Aggregation

The PHY PMI Aggregation Function defined in 61.2.2 allows multiple PMI interfaces to be aggregated together to form one logical link underneath one MII (or MAC). Additionally, the control mechanism allows multi-MAC devices to be built with flexible connections between the MACs and the PMIs. Clause 45 defines a mechanism for addressing and controlling this flexible connectivity. The relationship between the flexible connectivity and the other functions within the PCS is shown in Figure 61–2.

The connection relationship between the PCS instances (including MIIs) and the PMA/PMD instances (including PMI) is defined in two registers: PMD Available register (see 45.2.6.1) and PMD Aggregate register (see 45.2.6.2). The PMD Available register controls which loops (PMA/PMD instances) may be aggregated into a particular PMD. This register value is limited by the physical connectivity in the device, may be further constrained by management, and is additionally constrained as PMIs are aggregated into other PMDs (which causes their bit to be zero'd in the PMDs that they are not part of). The register represents the potential for connectivity into this PMD at the particular point in time. The PMD Aggregate register indicates the actual connectivity, i.e. which loops (PMA/PMD instances) are being aggregated into the particular PMD." Note that the addressing of PCS instances is independent of the addressing of PMA/PMD instances in order to support the flexible connectivity. This behavior may not be obvious to casual readers of Clause 45.

Note also that the definition of the PMD Available register may seem to imply that multiple MIIs may connect through the same PMI simultaneously but this is not the case. Bits corresponding to the same PMI may appear in multiple PMD Available registers but the PMD Aggregate register for each MII shall be set such that each PMI is only actively connected to one (or no) MII. A particular bit set in one PMD Aggregate register shall exclude the same corresponding bit in all other PMD Aggregate registers for the same MDIO connected system.

61.1.5.4.1 Addressing PCS and PMA/PMD instances

The addressing of the MDIO management interface is defined in 45.1. It is assumed that the reader is familiar with the definition of this interface. The examples here assume that only two MMDs are used: PCS (MMD = 3) and PMA/PMD (MMD = 1). The difference between these examples and the example shown in 45.1 is that the PCS instances are addressed independantly of the PMA/PMD instances. Up to 32 PCS instances and up to 32 PMA/PMD instances may be addressed by one MDIO bus. These instances may make up one or more aggregateable sub-domain. The connection of the MDIO bus to the MMDs is shown in Figure 61–3 .

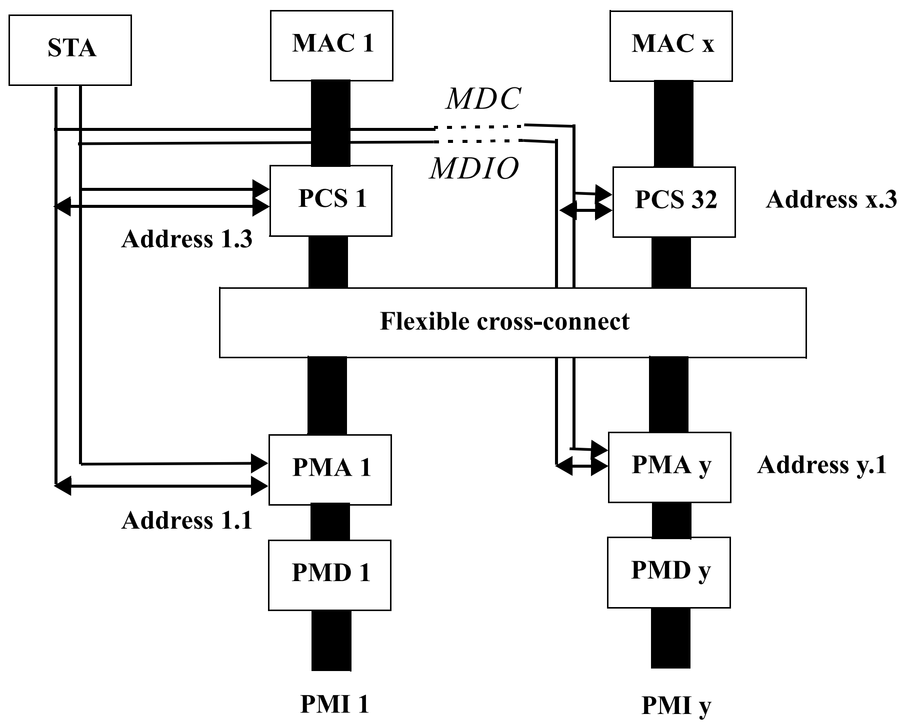

Figure 61–3—Connection of MDIO bus to MMD instances

In the example shown there is no necessary connection between the PCS address and the PMA/PMD address. Similarly, the number of PCS instances may be different from the number of PMA/PMD instances addressed by one MDIO bus.

61.1.5.4.2 Indicating PMI aggregation capability

The PMI aggregation capability is indicated by the state of the PMD Available register (see 45.2.6.1). A copy of this register is readable for each PAF instance *x* at register addresses *x*.3.45 and *x*.3.46. (Device address 3 of every port *x* is assigned to the PCS. The PAF is part of the PCS, as shown in Figure 61–2,which is why the PAF specific registers reside under the *x*.3 register tree.) A bit is set in this register corresponding to the PMA/PMD address for each PMA/PMD which can be aggregated through the PAF in that PCS. Some examples are given which show register contents and connectivity for some popular configurations:

a) Simple two PMI per MII connections, 32 PMIs (PMA/PMD instances) are aggregated into 16 MIIs (PCS instances). PMD available register contents are shown in Table 61–1. A diagram of the connectivity is shown in Figure 61–4 .

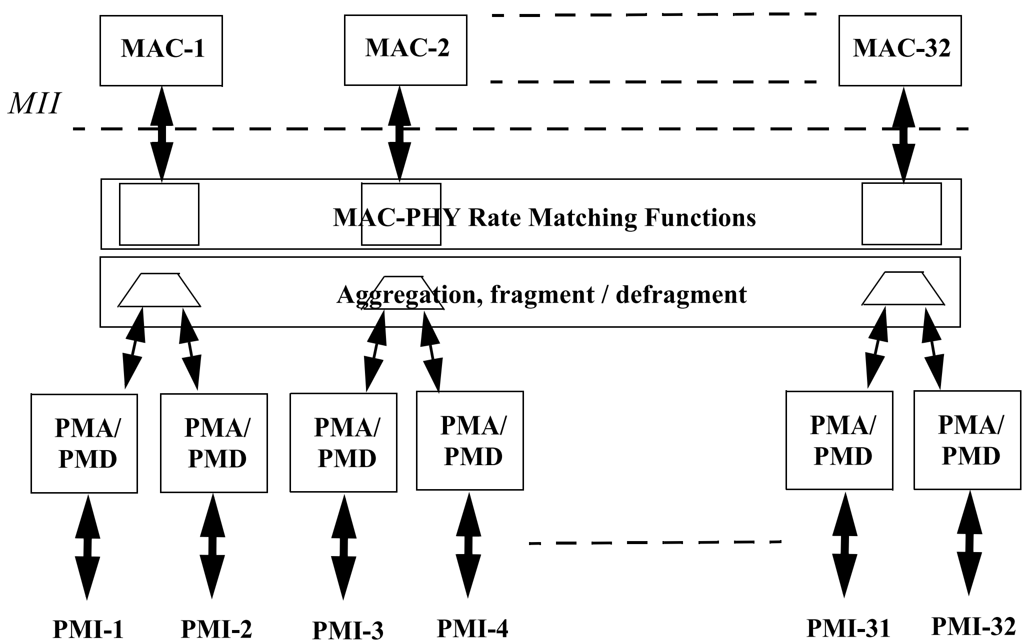

Figure 61–4—2 PMI for each MII connectivity

Table 61–1—PMD available register contents (example a)

PMD available register	Contents
1.3.45 / 46	b11000000_00000000_00000000_00000000
2.3.45 / 46	b00110000_00000000_00000000_00000000
etc.	etc.
16.3.45	b00000000_00000000_00000000_00000011

b) Pairs of 2-to-1 connections, 32 PMIs (PMA/PMD instances) are aggregated into 16 MIIs (PCS instances) in a manner that allows each PMI to connect to one of 2 MIIs and each MII to aggregate up to 4 PMIs. PMD available register contents are shown in Table 61–2. A diagram of the connectivity is shown in Figure 61–5 .

c) 12-to-24 fully flexible connections, 24 PMIs (PMA/PMD instances) are aggregated into 12 MIIs (PCS instances) in a manner that allows any PMI to connect to any MII. PMD available register contents are shown in Table 61–3. No connectivity diagram is shown as any connection is possible between PMIs and MIIs.

61.1.5.4.3 Setting PMI aggregation connection

The PMI aggregation connection is set using the PMD Aggregate register (see 45.2.2.2). This register is writeable for each PCS instance (x) at register addresses x.3.47 and x.3.48. A bit is set in this register corre-

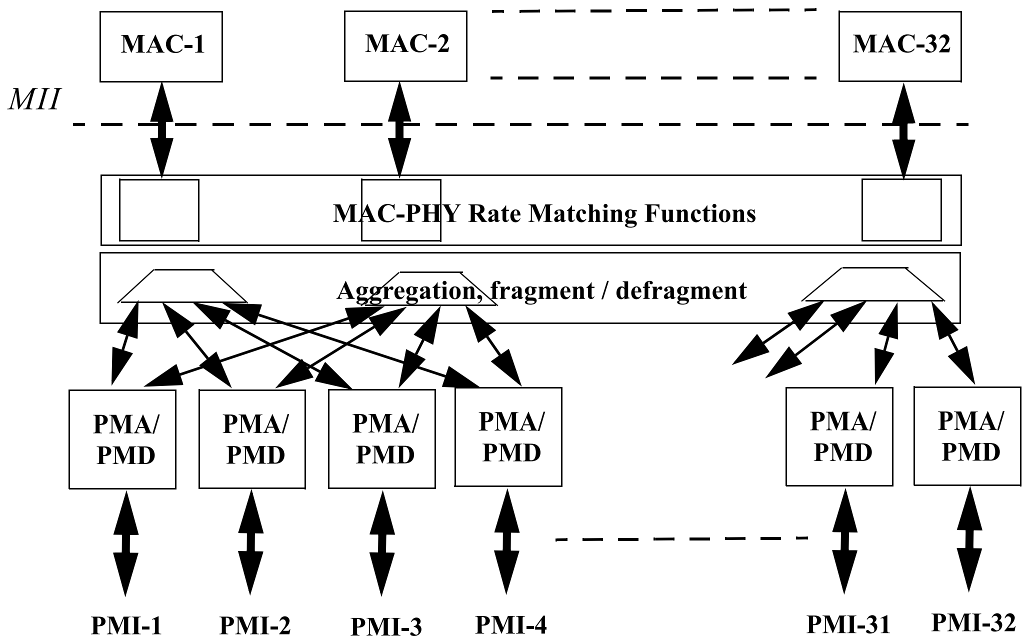

Figure 61–5—4 PMI for each 2 MII connectivity

Table 61–2—PMD available register contents (example b)

PMD available register	Contents
1.3.45 / 46	b11110000_00000000_00000000_00000000
2.3.45 / 46	b11110000_00000000_00000000_00000000
etc.	etc.
16.3.45	b00000000_00000000_00000000_00001111

Table 61–3—PMD available register contents (example c)

PMD available register	Contents
1.3.45 / 46	b11111111_11111111_11111111_00000000
2.3.45 / 46	b11111111_11111111_11111111_00000000
etc.	etc.
12.3.45	b11111111_11111111_11111111_00000000

sponding to the PMA/PMD address for each PMA/PMD which is to be aggregated through that PCS. Some examples are given which show register contents and connectivity for some popular configurations:

a) Simple two PMI per MII connections (as shown in example a above), the first MII aggregates 2 PMIs, the second MII only connects through 1 MII, as does the sixteenth. PMD aggregate register contents are shown in Table 61–4.

Table 61–4—PMD aggregate register contents (example a)

PMD aggregate register	Contents
1.3.47 / 48	b11000000_00000000_00000000_00000000
2.3.47 / 48	b00010000_00000000_00000000_00000000
etc.	etc.
16.3.47 / 48	b00000000_00000000_00000000_00000010

b) Pairs of 2-to-1 connections (as shown in example b above), the first MII aggregates 3 PMIs, the second MII only connects through 1 PMI, the sixteenth MII aggregates 2 PMIs. PMD aggregate register contents are shown in Table 61–5.

Table 61–5—PMD aggregate register contents (example c)

PMD aggregate register	Contents
1.3.47 / 48	b11100000_00000000_00000000_00000000
2.3.47 / 48	b00010000_00000000_00000000_00000000
etc.	etc.
16.3.47 / 48	b00000000_00000000_00000000_00000110

c) 12-to-24 fully flexible connections (as shown in example c above), the first MII aggregates 5 PMIs, the second MII only connects through the 24th PMI, the eleventh MII is not used, twelfth MII aggregates 2 PMIs. PMD aggregate register contents are shown in Table 61–6.

Table 61–6—PMD aggregate register contents (example c)

PMD aggregate register	Contents
1.3.47 / 48	b11111000_00000000_00000000_00000000
2.3.47 / 48	b00000000_00000000_00000001_00000000
etc.	etc.
11.3.47 / 48	b00000000_00000000_00000000_00000000
12.3.47 / 48	b00000000_00000000_00000110_00000000

61.1.5.5 Use of 2BASE-TL, 10PASS-TS PHY for point-to-point communication

Editor's Note: Text added in resolution of comment #678/D1.3:

The 10PASS-TS and 2BASE-TL EFM Copper PHYs, in conjunction with the MAC specified in Clauses 1 through 4 [see Clause 1-4], are used for point-to-point communications on a subscriber access network, typically between centralized distribution equipment, such as a Central Office (CO), and line termination equipment owned or controlled by a subscriber (Customer Premises Equipment, CPE).

For the 10PASS-TS and 2BASE-TL EFM Copper PHYs, two subtypes are defined: 10PASS-TS-O and 10PASS-TS-R are the subtypes of 10PASS-TS; 2BASE-TL-O and 2BASE-TL-R are the subtypes of 2BASE-TL. A connection can only be established between a 10PASS-TS-O PHY on one end of the voice-grade copper line, and a 10PASS-TS-R PHY on the other end, or between a 2BASE-TL-O PHY on one end and a 2BASE-TL-R PHY on the other end. In public networks, a 10PASS-TS-O or 2BASE-TL-O PHY is used at a CO, a cabinet or other centralized distribution point; a 10PASS-TS-R or 2BASE-TL-R PHY is used as CPE. In private networks, the network administrator will designate one end of each link as the CO side. In this Clause, 10PASS-TS-O and 2BASE-TL-O are collectively referred to as “CO-subtypes”; 10PASS-TS-R and 2BASE-TL-R are collectively referred to as “CPE-subtypes”.

Editor’s Note: Text added in resolution of comment #63001/D1.3:

The CO and CPE subtypes of a 10PASS-TS or 2BASE-TL PHY may be implemented in a single physical device. In this case, manual or automatic configuration will determine which role the PHY will take up to establish a link.

61.1.5.6 Support for handshaking

It is the goal of the ITU-T that all specifications for digital tranceivers for use on public telephone network copper subscriber lines use G.994.1 for startup. G.994.1 procedures allow for a common startup mechanism for identification of available features, exchange of capabilities and configuration information, and selection of operating mode. As the two loop endpoints are usually separated by a large distance (e.g., in separate buildings) and often owned and installed by different entities, G.994.1 also aids in diagnosing interoperability problems. G.994.1 codespaces have been assigned by ITU-T to ATIS T1, ETSI, and IEEE 802.3 in support of this goal.

The description of how G.994.1 procedures are used for Ethernet in the First Mile handshaking and PHY control are contained in 61.3.

61.2 PCS Functional Specifications

61.2.1 MAC-PHY Rate Matching functional specifications

61.2.1.1 MAC-PHY Rate Matching functions

The PHY shall use CRS to match the MAC's faster rate of data transmission to the PHY's slower rate.

Upon receipt of a MAC frame from on the MII, the PHY shall discard the Preamble and SFD fields, and transmit the resulting data frame across the physical link.

The PHY shall buffer a receive frame and prepend Preamble and SFD fields before sending it to the MAC at a rate of 100Mb/s.

The PHY shall support a mode of operation where it does not send data to the MAC while the MAC is transmitting.

61.2.1.2 MAC-PHY Rate Matching functional interfaces

61.2.1.2.1 MAC-PHY Rate Matching – MII signals

MII signals are defined in Table 23.2.2.1.

61.2.1.2.2 MAC-PHY Rate Matching–Management entity signals

The management interface has pervasive connections to all functions. Operation of the management control lines MDC and MDIO is specified in Clauses 22 [see Clause 22] and 45 [see Clause 45], and requirements for managed objects inside the PCS and PMA are specified in Clause 30 [see Clause 30].

61.2.1.3 MAC-PHY Rate Matching state diagrams

61.2.1.3.1 MAC-PHY Rate Matching state diagram constants

No constants are defined for the MAC-PHY rate matching state diagrams.

61.2.1.3.2 MAC-PHY Rate Matching state diagram variables

crs_rx
: Asserted by the MAC-PHY rate matching receive state machine to control CRS

TX_EN
: TX_EN signal of the MII as specified in Clause 22 [see Clause 22]

tx_buffer_available
: Set when the PHY's transmit FIFO has space to receive a maximum length packet from the MAC

crs_tx
: Asserted by the MAC-PHY rate matching transmit state machine to control CRS

CRS
: CRS signal of the MII as specified in Clause 22 [see Clause 22]. It is asserted when either of crs_tx or crs_rx are true: CRS ⇐ crs_tx + crs_rx

rx_frame_available
: Set when the PHY's receive FIFO contains one or more complete frames

RX_DV
: RX_DV signal of the MII as specified in Clause 22 [see Clause 22]

tx_rx_simultaneously
: True if the MAC is capable of transmitting and receiving simultaneously in half duplex mode

crs_and_tx_en_infer_col
: True if the MAC infers a collision when TX_EN and CRS are both true simultaneously.

61.2.1.3.3 MAC-PHY Rate Matching state diagram timer

rate_matching_timer

Timer used in rate matching state machine
Duration: 1120 ns, tolerance ±100 ppm.

The rate_matching_timer operates in a manner consistent with 14.2.3.2 [see Clause 14]. The timer is restarted on entry to the WAIT_FOR_TIMER_DONE state with the action: 'Start rate_matching_timer'. It is then tested in the exit condition with the expresssion "rate_matching_timer_done".

The duration is set to 1120 ns to allow 960 ns for the inter frame gap plus time for the MAC to recognize CRS.

61.2.1.3.4 MAC-PHY Rate Matching state diagrams

The state diagrams for the MAC-PHY Rate Matching functions are shown in Figure 61–6, Figure 61–7 and Figure 61–8.

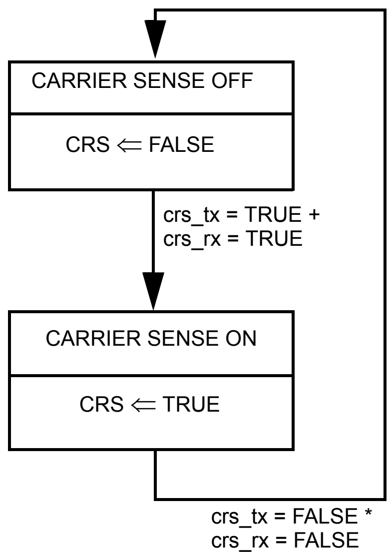

Figure 61–6—Carrier Sense state diagram

61.2.2 PHY PMI Aggregation functional specifications

This subclause defines an optional PHY PMI Aggregation Function (PAF) for use with CSMA/CD MACs in EFM copper PHYs. PMI Aggregation allows one or more PHYs to be combined together to form a single logical Ethernet link.

Editor's Note: There needs to be an indication of whether aggregation is available and provisioned or not. This will also include a description of operation without aggregation enabled (i.e. no fragmentation header etc.)

The PAF is located between the MAC-PHY Rate Matching function and the TPS-TC function as shown in Figure 61–2. The PAF interfaces with the TPS-TCs across the γ-interface. The PAF interfaces to the MAC-PHY Rate Matching function using an abstract interface whose physical realization is left to the implementor, provided the requirements of this standard are met.

The PHY PMI Aggregation function has the following characteristics:

a) Supports aggregation of up to 32 PHYs
b) Supports individual PHYs having different data rates
c) Ensures low packet latency and preserves packet sequence
d) Scalable and resilient to PHY PMI failure
e) Independent of type of EFM copper PHY
f) Allows vendor discretionary algorithms for fragmentation

61.2.2.1 PHY PMI Aggregation functions

The PHY PMI Aggregation functions provide a fragmentation procedure at the transmitter and a reassembly procedure at the receiver. The fragmentation and reassembly procedures take a standard data frame and par-

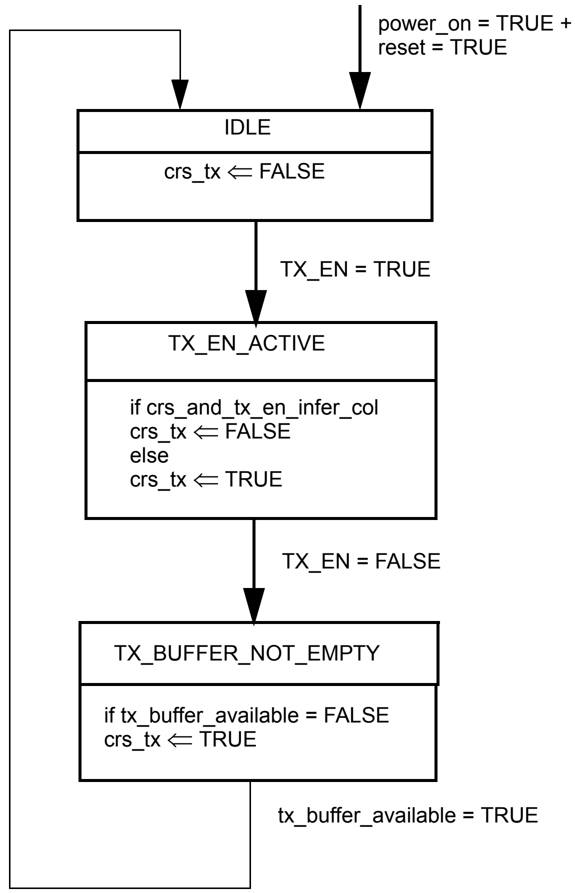

Figure 61–7—MAC-PHY rate matching transmit state machine

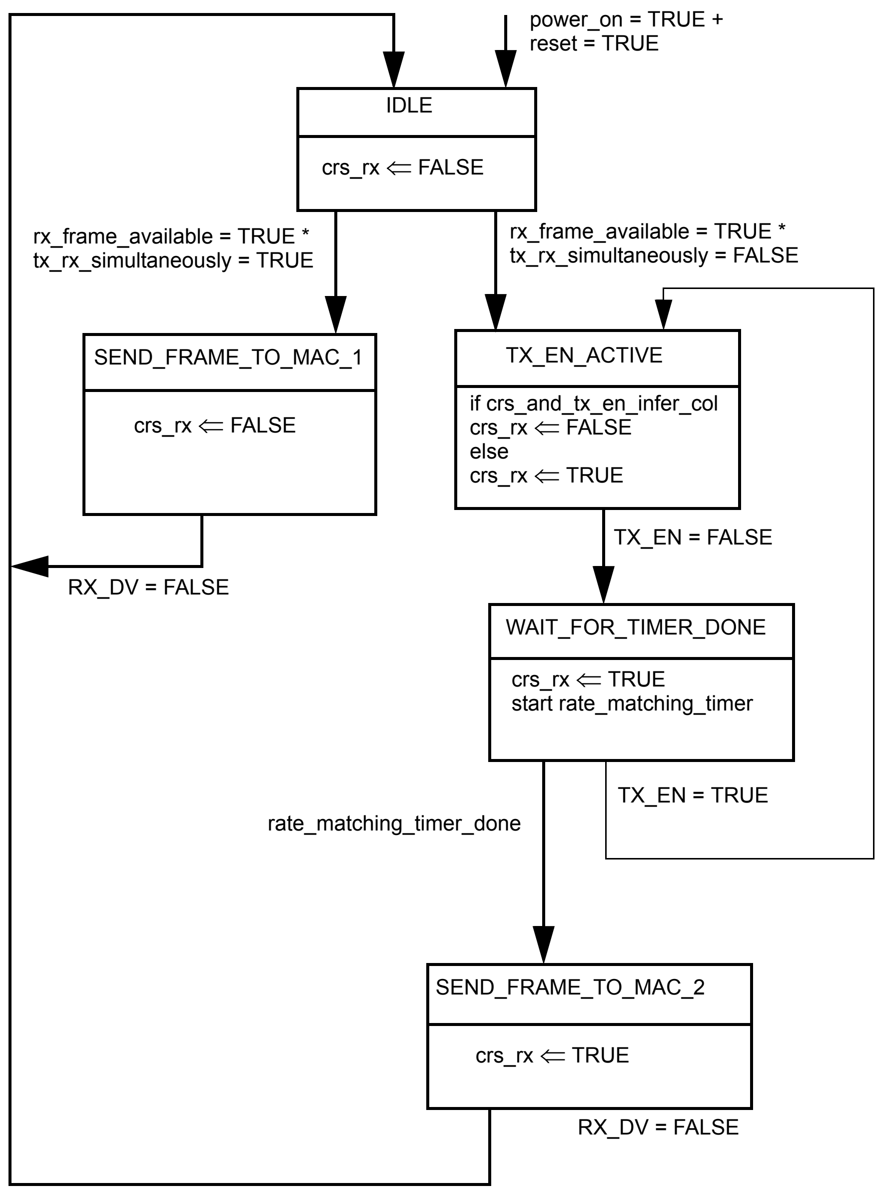

Figure 61–8—MAC-PHY rate matching receive state machine

tition it into one or more fragments as shown in Figure 61–9. Each fragment is given a fragment header and

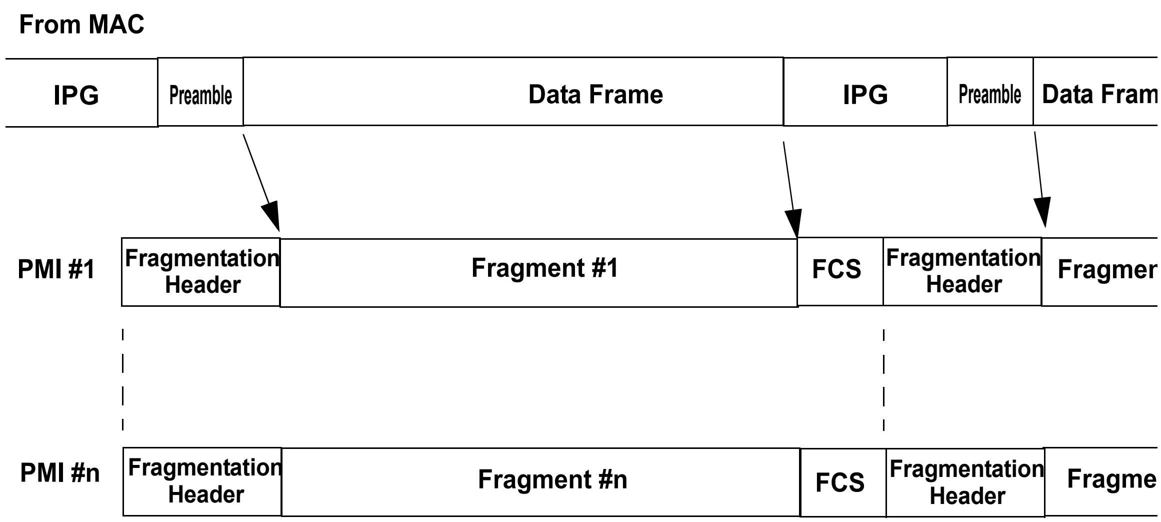

Figure 61–9—Data Frame Fragmentation

transmitted over a specific TPS-TC. A Frame Check Sequence is added to each fragment by the TPS-TC function. The fragmentation header has the format shown in Figure 61–10.

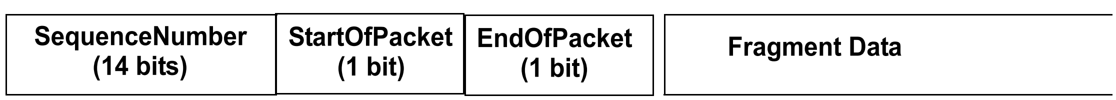

Figure 61–10—Fragmentation header format.

61.2.2.2 PHY PMI AGGREGATION Transmit function

The PHY PMI Aggregation transmit functions uses the following algorithm:

a) Select a PMI for the next transmission
b) Select the number of bytes to transmit on that PMI (shall be greater than minFragmentSize and less than maxFragmentSize)
c) Increment (modulo 2^{14}) and set fragment sequence number in the Fragmentation Header
d) Set the start-of-packet and end-of-packet bits in the Fragmentation Header as appropriate
e) Transmit fragment to the TPS-TC layer

It is important to note that the selection of the next PMI to use in transmission (step (a)) and the number of bytes to transmit (step (b)) is implementation dependent. However, implementations shall follow the restrictions as outlined in Section 61.2.2.4.

61.2.2.3 PHY PMI Aggregation Receive function

The PHY PMI aggregation receive function requires per-PMI queues as well as a per-MAC fragment buffer for fragment reassembly. The algorithm assumes only “good” fragments are placed on the per-PMI receive queues ("bad" fragments are discarded according to the rules in 61.2.2.5).

During initial start-up and in the event of certain errors, the receive algorithm has to determine which sequence number is expected next (expectedFragmentSequenceNumber). When the link state is changed to UP, the expected sequence number is unknown and no frame sequence errors shall be recorded. As fragments are received, expectedFragmentSequenceNumber is initialized to the smallest sequence number of fragments at the head of per-PMI queues when either all active queues are non-empty or at least one queue has been non-empty for maxDifferentialDelay bit times at the bit rate of the PMD associated with that queue.

In addition to the expected sequence number, it is necessary to determine the next sequence number (nextFragmentSequenceNumber). This is defined as the smallest sequence number of fragments at the head of per-PMI queues. Note that the sequence number rolls over after it reaches the maximum value, thus all sequence number comparisons shall use "split horizon" calculations. Split horizon calculations are defined for comparisons that are valid for numbers that roll over after reaching the maximum value. Generically, "x is less than y" is defined as x < y <= x + maxSequenceNumber/2.

The receive function executes the algorithm as shown in Figure 61–11

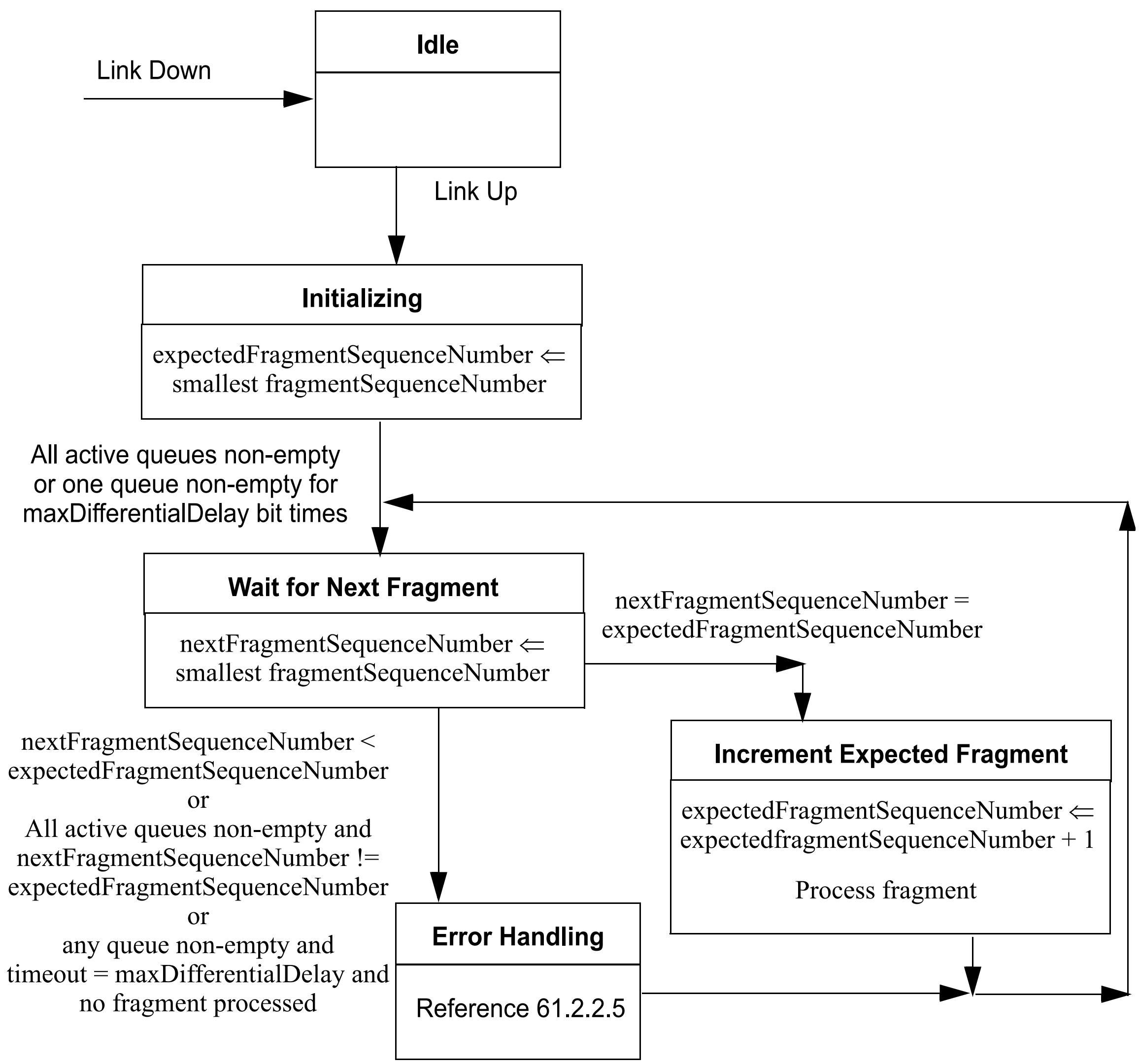

Figure 61–11—Aggregation Receive Function.

Aggregation receive algorithm:

a) Determine the nextFragmentSequenceNumber via the preceeding algorithm
b) If the nextFragmentSequenceNumber is equal to the expectedFragmentSequenceNumber, process that fragment and continue to step c). If (nextFragmentSequenceNumber is less than expectedFragmentSequenceNumber) or (all the active PMI queues are non-empty and nextFragmentSequenceNumber ≠ expectedFragmentSequenceNumber) or (any PMI queue has been non-empty for maxDifferentialDelay bit times without any fragment being processed) follow the fragment sequence error handling rules described in 61.2.2.5 before returning to normal fragment processing.
c) Accept the fragment into the fragment buffer. If that fragment is an end-of-packet, pass the packet to the MAC-PHY Rate Matching layer.
d) Increment the expectedFragmentSequenceNumber
e) Repeat processing.

Subclause 61.2.2.4 restricts the transmit function such that the maximum buffer requirement for a receiver is 2^{14} bits per PMI or 2^{12} bits for 2BASE-TL only systems.

61.2.2.4 PHY PMI Aggregation Transmit Function Restrictions

There are factors that limit the freedom of the transmission algorithm specified in Section 61.2.2.2

One factor is the differential latency between multiple PMIs in an aggregated group. Differential latency measures the variation in the time required to transmit across different PMIs. To normalize the latency measurement for high and low speed links, differential latency is measured in bit times. A differential latency of N bit times implies that N bits can be sent across one PMI in by the time a single max size fragment makes it across the other. Larger differential latencies imply greater variance in bit delivery times across aggregated PMIs, which in turn require larger sequence number ranges. The PMD control of aggregated links shall control the maximum latency difference between any two aggregated links. This is achieved by adjusting the bit rate, error correction and interleaving functions in the PMA/PMD of each link. Note that the burst noise protection offered by the error correction and interleaving functions is directly proportional to the latency, therefore it is logical that multiple aggregated links in the same environment should be optimized to have similar latencies.

A second factor is the size of the fragments being transmitted across the PMIs. Very small fragments require larger sequence number ranges as there can be more fragments within the same number of bit times.

The third factor is the speed ratio. This is defined as the ratio of the bit rate of the faster link divided by the slower link.

The restrictions for the transmission algorithm in Section 61.2.2.2 are:

a) The differential latency between any two PMIs in an aggregated group shall be no more than 15,000 bit times for 10PASS-TS or 8,000 bit times for 2BASE-TL (maxDifferentialDelay).
b) Fragments shall not be less than 64 Bytes (minFragmentSize).
c) Fragments shall not be more than 512 Bytes (maxFragmentSize).
d) The highest ratio of speeds between any two aggregated links shall be 4 (maxSpeedRatio).
e) The fragment size shall be a multiple of 4 bytes except for the last fragment of a packet.

These restrictions allow the use of a 14-bit sequence number space.

61.2.2.5 Error-detecting Rules

There are three classes of error detected by the PAF: Errors during fragment reception; Errors in fragment sequencing; and Errors during packet reassembly.

Errors during fragment reception:

The receive TC function passes all decapsulated frames to the PAF across the γ-interface. If the TC detects an error in the encapsulation, it asserts Rx_Err during the frame transmission on the γ-interface.

For each PMA (γ-interface), the per-PMA buffering mechanism shall discard the fragment if any of the following conditions occur:

Rx_Err is asserted during the reception of the fragment across the γ-interface.
The fragment is too small - less than minFragmentSize as defined in 61.2.2.4.
The fragment is too large - more than maxFragmentSize as defined in 61.2.2.4.
The fragment would cause the per-PMA received buffer to overflow.

The PAF shall then assert one of the per-PMA error flags as appropriate:

TC_PAF_RxErrorReceived; TC_PAF_FragmentTooSmall; TC_PAF_FragmentTooLarge;
TC_PAF_Overflow.

Errors in fragment sequencing:

If nextFragmentSequenceNumber is outside the range (expectedFragmentSequenceNumber through expectedFragmentSequenceNumber + 2^{11}) then assert PAF_BadFragmentReceived. Discard the fragment, do not increment ExpectedFragmentSequenceNumber.

If all active PMA buffers are non empty and nextFragmentSequenceNumber is greater than expectedFragmentSequenceNumber then assert PAF_LostFragment, set expectedFragmentSequenceNumber equal to nextFragmentSequenceNumber.

If any PMA buffer is non empty for maxDifferentialDelay bit times (for that PMA/PMD) and no fragment is transferred then assert PAF_LostFragment, set expectedFragmentSequenceNumber equal to nextFragmentSequenceNumber.

Having detected one of the above fragment sequencing errors, the packet assembly function shall act as follows:

If the packet assembly function was mid-frame (i.e. waiting for an End of Packet), the first part of the frame shall be transferred across the MII, then assert RX_ER signal on MII interface, abort frame transfer and flush PMA buffers until the next Start of Packet is received.

If the packet assembly function was between frames (i.e. waiting for a Start of Packet), assert RX_ER signal on the MII interface, send 64 byte garbage frame with forced FCS error to MAC, flush PMA buffers until the next Start of Packet is received. The garbage frame shall consist of 64 bytes of 00_{16} to which a preamble and SFD will be prepended according to 61.x.x.x *(editor to change TBD reference here)*.

Errors in packet reassembly:

If a fragment is received with the EndOfPacket bit asserted while the packet assembly function was between frames (i.e. waiting for a Start of Packet), assert RX_ER signal on the MII interface, send 64 byte garbage frame with forced FCS error to MAC, flush PMA buffers until the next Start of Packet is received. Assert PAF_LostStart. The garbage frame shall consist of 64 bytes of 00_{16} to which a preamble and SFD will be prepended according to 61.x.x.x *(editor to change TBD reference here)*.

If a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame (i.e. waiting for an End of Packet), the first part of the frame shall be transferred across the MII, then assert RX_ER signal on MII interface, abort frame transfer and flush PMA buffers until the next Start of Packet is received. Assert PAF_LostEnd

If a fragment is received while the packet assembly function was mid-frame (i.e. waiting for an End of Packet) and would cause the frame size to exceed the maximum allowable frame size i.e. 1522 bytes (see 3.5, 4.2.7.1 and 4.4) then the first part of the frame shall be transferred across the MII, then assert RX_ER signal on MII interface, abort frame transfer and flush PMA buffers until the next Start of Packet is received. Assert PAF_LostEnd.

61.2.2.6 PHY PMI Aggregation functional interfaces

The PAF interfaces with the TPS_TCs across the γ-interface. The PAF interfaces to the MAC-PHY Rate Matching function using an abstract interface whose physical realization is left to the implementor, provided the requirements of this standard are met.

61.2.2.6.1 PHY PMI AGGREGATION–γ-interface signals

The PAF interfaces with the PHYs across the γ-interface. The γ-interface specification is defined in 61.2.3.1. This subclause specifies the data, synchronization and control signals that are transmitted between the TPS-TC and the PAF.

61.2.2.6.2 PHY PMI AGGREGATION–Management entity signals

The PAF provides the following Management Entity primitives:

TC_PAF_RxErrorReceived: (for each PMA, γ-interface) this primitive is asserted to indicate that a fragment has been received across the γ-interface with RxErr asserted. The errored fragment has been discarded.

TC_PAF_FragmentTooSmall: (for each PMA, γ-interface) this primitive is asserted to indicate that a fragment has been received across the γ-interface which was smaller than the minFragmentSize defined. The errored fragment has been discarded.

TC_PAF_FragmentTooLarge: (for each PMA, γ-interface) this primitive is asserted to indicate that a fragment has been received across the γ-interface which was larger than the maxFragmentSize defined. The errored fragment has been discarded.

TC_PAF_Overflow: (for each PMA, γ-interface) this primitive is asserted to indicate that a fragment has been received across the γ-interface which would have caused the receive buffer to overflow. The errored fragment has been discarded.

PAF_BadFragmentReceived: this primitive is asserted to indicate that a fragment has been received which does not fit into the sequence expected by the frame assembly function. The errored fragment has been discarded and the frame buffer flushed to the next valid frame start.

PAF_LostFragment: this primitive is asserted to indicate that a fragment (or fragments) expected according to sequence has not been received by the frame assembly function. The missing fragment (or fragments) has been skipped and the frame buffer flushed to the next valid frame start.

PAF_LostStart: this primitive is asserted to indicate that the packet reassembly function did not receive a StartOf Packet indicator in the appropriate sequence.

PAF_LostEnd: this primitive is asserted to indicate that the packet reassembly function did not receive an EndOfPacket indicator in the appropriate sequence.

61.2.2.6.3 PHY PMI aggregation register functions

Clause 45 [see Clause 45] defines 2 registers which relate to the PHY PMI aggregation function: the PMD_Available_register and the PMD_Aggregate_register. Additionally the remote_discovery_register and Aggregation_link_state_register shall be implemented.

The PMD_Available_register is read-only for CO-subtype and may be writeable for CPE-subtype (in order to restrict CPE-subtype connection capability according to 45.2.6.1). It indicates whether an aggregateable link is possible between this PCS and multiple PMD's. For a device that does not support aggregation of multiple PMIs, a single bit of this register shall be set and all other bits clear. The position of bits indicating aggregateable PMI links correspond to the PMA/PMD sub-address defined in Clause 45.

For CPE-subtype devices, the PMD_Available_register may optionally be writeable by the local management entity. The reset state of the register reflects the capabilities of the device. The management entity (through Clause 45 access) may clear bits which are set, in order to limit the mapping between MII and PMI for PMI aggregation. For CPE-subtype devices, PMD links shall not be enabled (such that no handshaking starts) until the PMD_Available register has been set to limit the connectivity such that each PMI maps to one, and only one MII (45.2.6.1). Multiple PMI's per MII are allowed.

Editor's Note: The accepted remedy per editorial comment #764/D1.3 has not been implemented on the previous paragraph because it, in fact, makes a technical change. The original text was intended to describe the writability of the register from the CPE-side, not the CO-side. This technical change contradicts the function of the register as defined in other sections (and also contradicts the baseline). The text has been changed to make the function clearer as per the spirit of the comment.

The PMD_Aggregate_register is defined in Clause 45. For CO-subtype devices, access to this register is through Clause 45 register read and write mechanisms. For CPE-subtype devices the register may be read locally through Clause 45, reads and writes shall be allowed from remote devices via the remote access signals passed across the γ-interface from the PMA *(***Editor's Note: add reference TBD to Clause 61.3 here***)*. The operation of the PMD_Aggregate_register for CPE-subtype devices is defined as follows:

a) If the remote_discovery_register is clear then the PMD_aggregate_register shall be cleared.

b) If write_PMD_Aggregation_reg is asserted, the contents of remote_write_data bit zero is written to PMD_Aggregation_register in the bit location corresponding to the PMA/PMD from which the request was received. Acknowledge_read_write is asserted for one octet clock cycle.

c) If read_PMD_Aggregation_reg is asserted, the contents of PMD_Aggregation_register are placed onto remote_read_data bus, bits 31 through 0. Unsupported bits are written as zero if the full width of PMD_Aggregation_register is not supported. Acknowledge_read_write is asserted for one octet clock cycle.

The remote_discovery_register shall be implemented for CPE-subtype devices. The remote_discovery_register may be read locally through Clause 45 [see Clause 45] register access mechanisms. The remote_discovery_register shall support atomic write operations and reads from remote devices via the remote access signals passed across the γ-interface from the PMA ***(editor's note: add reference TBD to Clause 61.3 here)***. The operation of the remote_discovery_register for CPE-subtype devices is defined as follows:

a) If read_remote_discovery_reg is asserted, the contents of remote_discovery_register are placed onto remote_read_data bus. Acknowledge_read_write is asserted for one octet clock cycle.

b) If write_remote_discovery_reg is asserted, the action depends on the contents of remote_discovery_register. If the remote_discovery_register is currently clear (no bits asserted), the contents of the remote_write_data bus are placed into the remote_discovery_register. The new contents of remote_discovery_register are placed on the remote_read_data bus. Acknowledge_read_write is asserted for one octet clock cycle. Else if the remote_discovery_register is not currently clear (any bit asserted), no data is written. The old contents of remote_discovery_register are placed on the remote_read_data bus. NAcknowledge_read_write is asserted for one octet clock cycle. If multiple write_remote_discovery_reg signals are asserted (from multiple γ-interfaces) they shall be acted upon serially.

c) If clear_remote_discovery_reg is asserted, the remote_discovery_register is cleared. The new contents of remote_discovery_register are placed on the remote_read_data bus. Acknowledge_read_write is asserted for one octet clock cycle.

d) If the logical AND of the Aggregation_link_state_register and the PMD_Aggregate_register is clear then a timeout counter shall be started. If this condition continues for 30 seconds (the timeout period) then the remote_discovery_register shall be cleared.

Note that a single device may be implemented which has multiple MII interfaces and (therefore) multiple PCS instances. There shall be one remote_disovery_register per PCS instance. The PMD_available register shall be set prior to the enabling of links so that each PMA/PMD is linked to only one PCS. Access to the remote_discovery_register (read or write) shall be restricted to PMA/PMD instances for which the corresponding PMD_available register bit is asserted.

The Aggregation_link_state_register is a pseudo-register corresponding to the PCS_link_state bits from each γ-interface in the appropriate bit positions according to the PMA/PMD from which the signal is received. Bits corresponding to unsupported aggregation connections are zero.

61.2.2.6.4 PHY PMI AGGREGATION – remote access of remote_discovery_register

As the CO-subtype accesses the remote_discovery_register in the CPE-subtype prior to training and establishment of the PMD-to-PMD link, it is performed using G.994.1 handshake messages.

2BASE-TL and 10PASS-TS PHY's shall assert the PMI Aggregation Discovery SPar(2) bit in all G.994.1 CLR messages. CPE-subtype's shall place the contents of the remote_discovery_register in the corresponding NPar(3) bits in the outgoing CLR message, with the Clear if Same NPar(3) set to zero.

In response to a "Get" command, the CO-subtype shall perform a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar(3) PMI Aggregation register bits in the CLR message received from the CPE-subtype shall be reported as the result. The CL message sent by the CO-subtype in response to the CLR shall have the PMI Aggregation Discovery SPar(2) bit set to zero.

In response to a "Set if Clear" command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) PMI Aggregation register in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PMI Aggregation Discovery SPar(2) bit set to one, the Clear if Same NPar(3) bit set to zero, and the NPar(3) PMI Aggregation register bits set to the CO-subtype PMI Aggregation Discovery Code register. The CPE-subtype shall set the remote_discovery register to this value if it is currently clear. The contents of the NPar(3) PMI Aggregation register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PMI Aggregation Discovery SPar(2) bit set to zero.

In response to a "Clear if Same" command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) PMI Aggregation register in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PMI Aggregation Discovery SPar(2) bit set to one, the Clear if

Same NPar(3) bit set to one, and the NPar(3) PMI Aggregation register bits set to the CO-subtype PMI Aggregation Discovery Code register. The CPE-subtype shall clear the remote_discovery register if it is currently equal to this value. The contents of the NPar(3) PMI Aggregation register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PMI Aggregation Discovery SPar(2) bit set to zero.

61.2.3 TPS-TC functional specifications

The functional model of the TPS-TC sublayer is presented in Figure 61–12. The term "TPS-TC" is borrowed from the definition in ITU-T Recommendation G.993.1. In this context the term "TC = Transmission Convergence" is sufficient as no other types of TC are defined in this subclause (e.g. PMS-TC). Hence, in the interest of brevity, this subclause will use "TC" within the text and diagrams.

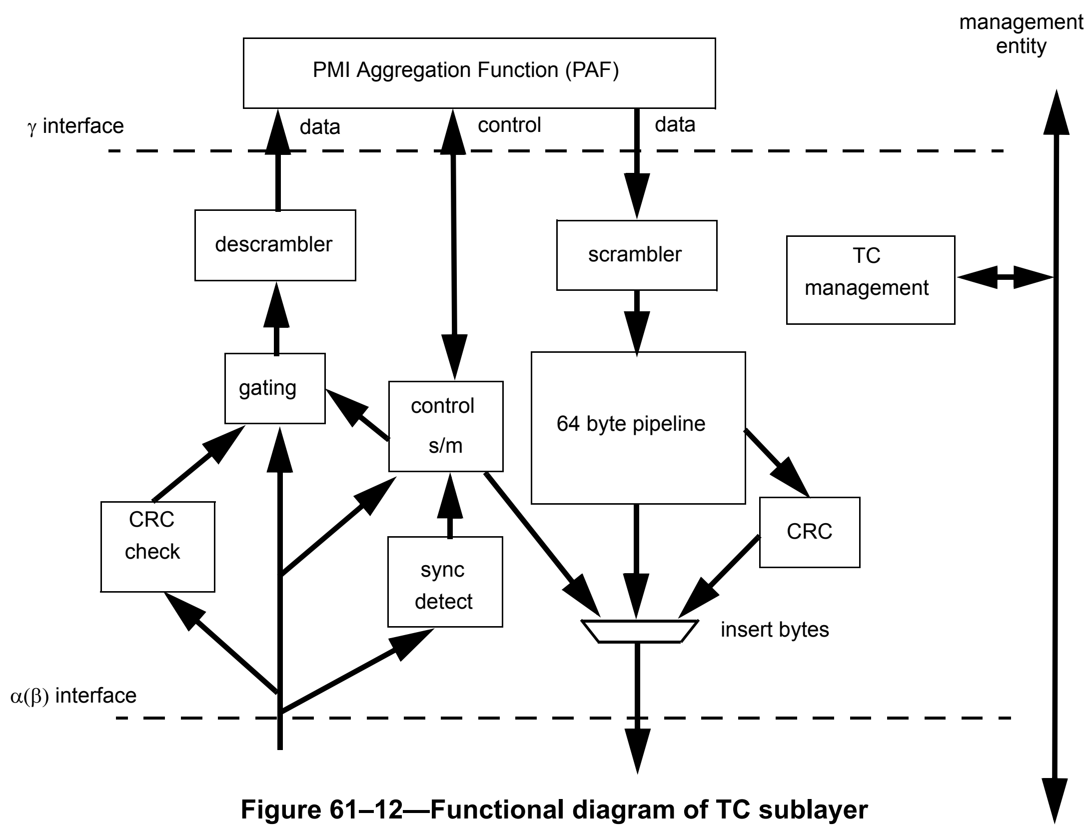

Figure 61–12—Functional diagram of TC sublayer

61.2.3.1 The γ interface

The γ interface is specified by incorporating section H.3.1 and all subsubsections of ITU-T Recommendation G..993.1 (Annex H) by reference, with the following exceptions and additions:

The PAF shall assert Tx_Avble when it has a whole data fragment available for transmission, and de-assert Tx_Avble when there are no data fragments to transmit. Tx_Avble must never be de-asserted during the transmission of a data fragment.

Additional Paragraph: OAM Information flow across the γ-interface will support access to the registers defined in Clause 45 [see Clause 45]. Refer to Clause 45 [see Clause 45] for a complete description of access to TC, PMA and PMD registers from the MDIO interface.

Additional signals, which would be represented in the referenced document section H.3.1.4, are described in Table 61–7.

Table 61–7—Additional γ interface signals for OAM

Signal	Size	Description	Direction
PCS_link_state	1 bit	Control signal asserted when link is active and framing has synchronized according to the definition in subclause 61.2.3.3.	TC → PAF
write_remote_aggregation_reg	1 bit	Control signal to write PMD_aggregation_register. Active (min) 1 octet clock cycle	TC →PAF
write_remote_discovery_reg	1 bit	Control signal to write remote_discovery_register. Active (min) 1 octet clock cycle	TC →PAF
clear_remote_discovery_reg	1 bit	Control signal to clear remote_discovery_register. Active (min) 1 octet clock cycle	TC → PAF
read_remote_aggregation_reg	1 bit	Control signal to read PMD_aggregation_register. Active (min) 1 octet clock cycle	TC → PAF
read_remote_discovery_reg	1 bit	Control signal to read remote_discovery_register. Active (min) 1 octet clock cycle	TC →PAF
remote_write_data_bus	48 bit	Data bus for writing to PMD PMI aggregation registers. Valid during octet clock cycle when write control is asserted	TC → PAF
remote_read_data_bus	48 bit	Data bus for the results of a read or atomic write function. Valid during octet clock cycle when Acknowledge_read_write or NAcknowledge read_write is asserted	PAF→ TC
Acknowledge_read_write	1 bit	Control signal responding (positively) to read or write. Active 1 octet clock cycle	PAF → TC
NAcknowledge read_write	1 bit	Control signal responding (negatively) to read or write. Active 1 octet clock cycle	PAF → TC

61.2.3.2 The α(β) interface

The α(β) interface is specified by incorporating section 7.1 and all subsections of ITU-T Recommendation G..993.1 by reference.

The α and β reference points define interfaces between the PCS and PMA in the 2BASE-TL-O/10PASS-TS-O and the 2BASE-TL-R/10PASS-TS-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flow:

a) Data flow
b) Synchronization flow
c) OAM flow[1]

61.2.3.2.1 α(β) Data Flow

The data flow consists of two generic octet-oriented streams with bit rates defined by the PMD transmission capabilities:

a) Transmission data streams: (Tx_s)
b) Reception data streams: (Rx_s)

The data flow signals are described in Table 61–8. If data streams are implemented serially, the MSB of each octet is sent first.

Table 61–8— α(β) Interface signals

Signal(s)	Description	Direction	Notes
Tx_s	Transmitted data	PCS → PMA	
Rx_s	Received data	PCS ← PMA	
Osync_t	Transmitted octet timing	PCS ← PMA	
Osync_r	Received octet timing	PCS ← PMA	
Clk_t	Transmit bit timing	PCS ← PMA	Optional
Clk_r	Receive bit timing	PCS ← PMA	Optional
Fsync_t	Transmit frame timing	PCS ← PMA	Optional
Fsync_r	Receive frame timing	PCS ← PMA	Optional
PMA_receive_ synchronized	Receive PMA state machine synchronized	PCS → PMA	

61.2.3.2.2 α(β) Synchronization Flow

The synchronization flow is comprised of the following synchronization signals:

a) Transmission data flow octet synchronization (Osync_t)
b) Reception data flow octet synchronization (Osync_r)
c) Transmit and receive data flow bit-synchronization (Clt_t, Clk_r), optional
d) Transmit and receive data flow frame-synchronization (Fsync_t, Fsync_r), optional.
e) Receive PMA state machine synchronized (PMA_receive_synchronized)

[1]The term “OAM” as used here refers to the OAM facilities as defined in the referenced G.993.1 document.

The synchronization signals are asserted by the PMA and directed towards the PCS. The synchronization flow signals are described in Table 61–8.

61.2.3.2.3 α(β) OAM Flow

The OAM Flow across the α(β)-interface exchanges OAM information between the PHY-OAM entity, the PMA and the PMD. The OAM flow is bidirectional and transports line related primitives, parameters, configuration setup and maintenance signals or commands.

The OAM information flow across the γ interface will support access to the registers defined in Clause 45 [see Clause 45]. Refer to Clause 45 [see Clause 45] for a complete description of access to TC, PMA and PMD registers from the MDIO interface.

Refer to Clauses 62 and 63 for definitions of the G.994.1 messaging, Operation Channel (OC) and Indicator Bits (IB) mechanisms for accessing remote parameters.

61.2.3.3 TC functions

The TC shall provide full transparent transfer of data frames between γ_O and γ_R interfaces (except non-correctable errors caused by the transmission medium). It shall also provide fragment integrity and fragment error monitoring capability.

In the transmit direction, the TC receives fragments from the PAF via the γ interface. Data is first scrambled, and then an additional 32-bit CRC is calculated and appended. The TC then performs 64Byte/65Byte encapsulation, and sends the resulting codewords to the PMA via the α(β) interface. In the receive direction, the TC receives codewords from the PMA via α(β) interface, recovers the transported TC frame, and submits the extracted fragment to the PAF via the γ interface.

The bit rate of data transport in the upstream and downstream directions may be set independently of each other to any eligible value up to the maximum rate determined by the PMD. Both the upstream and downstream maximum data bit rates are set during the system configuration.

An implementation is shown in Figure 61–13 and some example timing diagrams are shown in Figure 61–14.

61.2.3.3.1 Scrambler

The scrambler used is identical to the definition in Clause 49. Data received on the γ interface is scrambled with a self-synchronizing scrambler. The scrambler shall produce the same result as the implementation shown in Figure 61–15

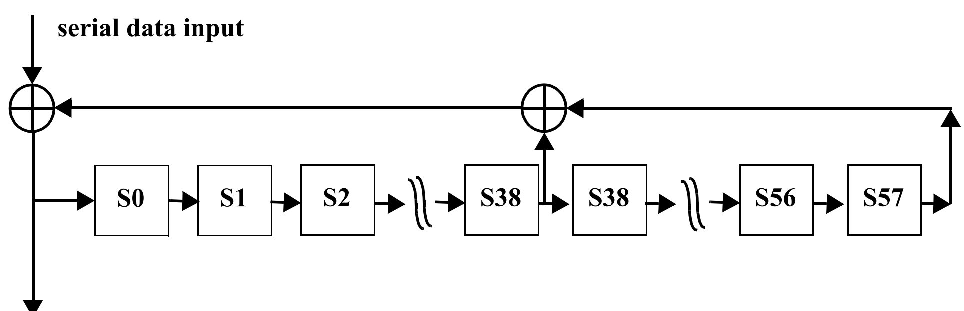

Figure 61–15—Scrambler

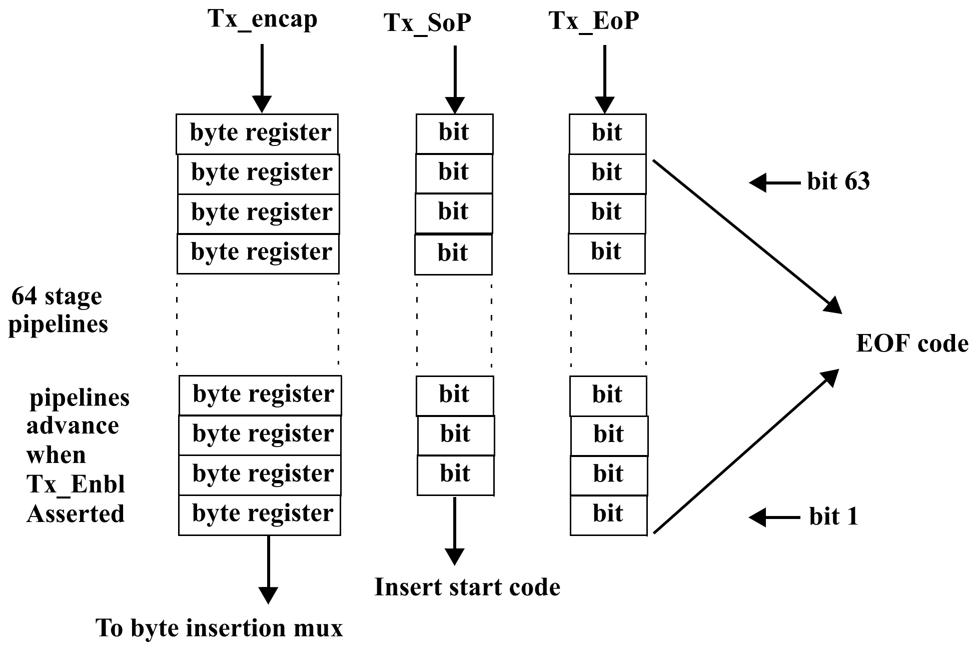

Figure 61–13—Example transmit pipeline

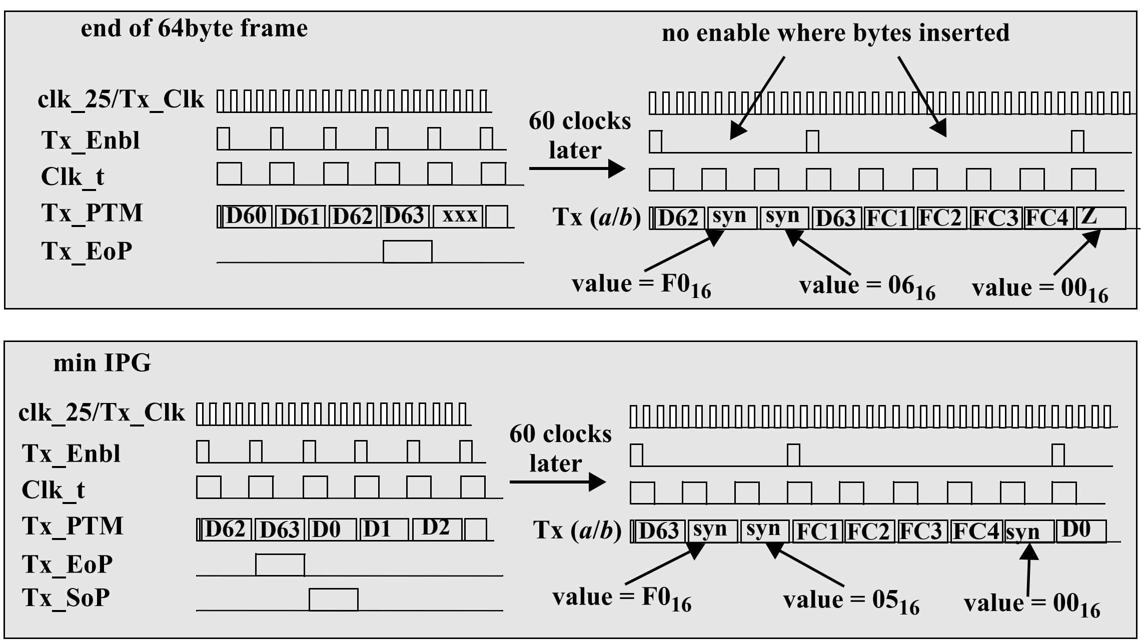

Figure 61–14—Example transmit timing

. This implements the scrambler polynomial[2]:

[2]The convention here, which considers the most recent bit into the scrambler to be the lowest order term, is consistent with most references and with other scramblers shown in this standard. Some references consider the most recent bit into the scrambler to be the highest order term and would therefore identify this as the inverse of the polynomial in equation (1). In case of doubt, note that the conformance requirement is based on the representation of the scrambler in the figure rather than the polynomial equation.

$$G(x) = 1 + x^{39} + x^{58} \quad (1)$$

There is no requirement on the initial value for the scrambler. The scrambler is run continuously on all payload bits. Sync header, control, and CRC bytes are inserted after scrambling, and thus bypass the scrambler.

61.2.3.3.2 Descrambler

The descrambler processes the payload to reverse the effect of the scrambler using the same polynomial. It shall produce the same result as the implementation shown in Figure 61–16

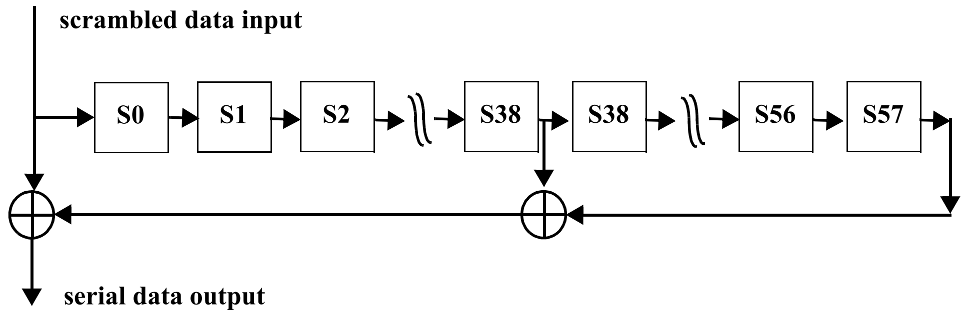

Figure 61–16—Descrambler

61.2.3.3.3 TC Encapsulation and Coding

A TC frame consists of a scrambled data frame (either a MAC Frame or a PMI aggregation fragment), followed by a 32-bit CRC as defined in 61.2.3.3.5.

The TC coding function generates codewords with a fixed length of 65 Bytes (64B/65B coding). A codeword consists of a Sync Byte and one of the following combinations:

a) all data: all of the octets in the codeword belong to the same TC frame.
b) end of frame (go to idle): up to 63 octets in the codeword belong to the same TC frame, the rest of the codeword consists of Idle octets.
c) end of frame (start new frame): up to 62 octets in the codeword belong to the same TC frame, a number of Idle octets and a single Start of Frame octet precede the first data octets of the next TC frame.
d) all idle: all of the octets in the codeword are Idle octets.
e) all idle (start new frame): a number of Idle octets and a single Start of Frame octet precede up to 63 data octets of the next TC frame.

Both transmit and receive data may be transferred across both the $\alpha(\beta)$ and the γ interfaces at rates that are different from the rate across the MII; the frame buffering is managed in the sublayer above the γ interface. The TC layer uses the γ interface flow control signal, Tx_Enbl, to slow egress data to the rate required for the encapsulated data across the $\alpha(\beta)$ interface. The TC layer uses the γ interface flow control signal, Rx_Enbl, to allow idle cycles in the flow of ingress data across the γ interface.

When a frame arrives from the γ interface while an End of Frame codeword is being transmitted, a Start of Frame octet shall be inserted prior to the transmission of data octets belonging to the next frame. The Start of Frame octet *S* is distinct from the Idle octet *Z*. Valid locations for *S* are any valid location for Z, and the presense of an *S* rather than a *Z* octet indicates that what follows is the commencement of data for a new frame.

The data and sync format of the encapsulated data is shown in Table 61–9.

The end of a TC frame frame is always marked with an End of Frame codeword; e.g., the received sequence [All Data codeword][All Idle codeword] is considered a sequencing error.

Table 61–9—Codeword formats

Type	Frame Data	Sync Byte	Byte fields 1-64									
all data	DDDD---DDDD	$0F_{16}$	D_0	D_1	D_2	D_3	D_4	D_5	...	D_{61}	D_{62}	D_{63}
end of frame	contains *k* D's, where *k*=0 to 63	$F0_{16}$	C_k	D_0	D_1	D_2	D_3	...	D_{k-1}	Z	...	Z
all idle	ZZZZ---ZZZZ	$F0_{16}$	Z	Z	Z	Z	Z	Z	...	Z	Z	Z
start of frame while idle	contains *k* D's, where *k*=0 to 63, and contains *j* Z's, where *j*=63-*k*	$F0_{16}$	Z	Z	S	D_0	D_1	...	...	D_{k-3}	D_{k-2}	D_{k-1}
start of frame while trans-mitting.	contains last *k* D's of 1st frame, where *k*=0 to 62; & first *j* D's of 2nd frame, where *j*=0 to 62-*k*	$F0_{16}$	C_k	D_0	...	D_{k-1}	Z	...	S	D_0	...	D_{j-1}

Figure 61–17— Illustrates two interesting examples. In the first example, the last 60 bytes of a scrambled data frame, plus the 4 encapsulation CRC bytes, are transmitted in an All Data codeword. In other words, the end of the (CRC-augmented) frame coincides with the end of the codeword. In this case, the next codeword begins with Sync Byte equal to $F0_{16}$, C_n equal to C_0 (81_{16}). The second codeword indicates an End Of Frame, but with no additional data; in other words, the data in the previous codeword were the last of the frame.

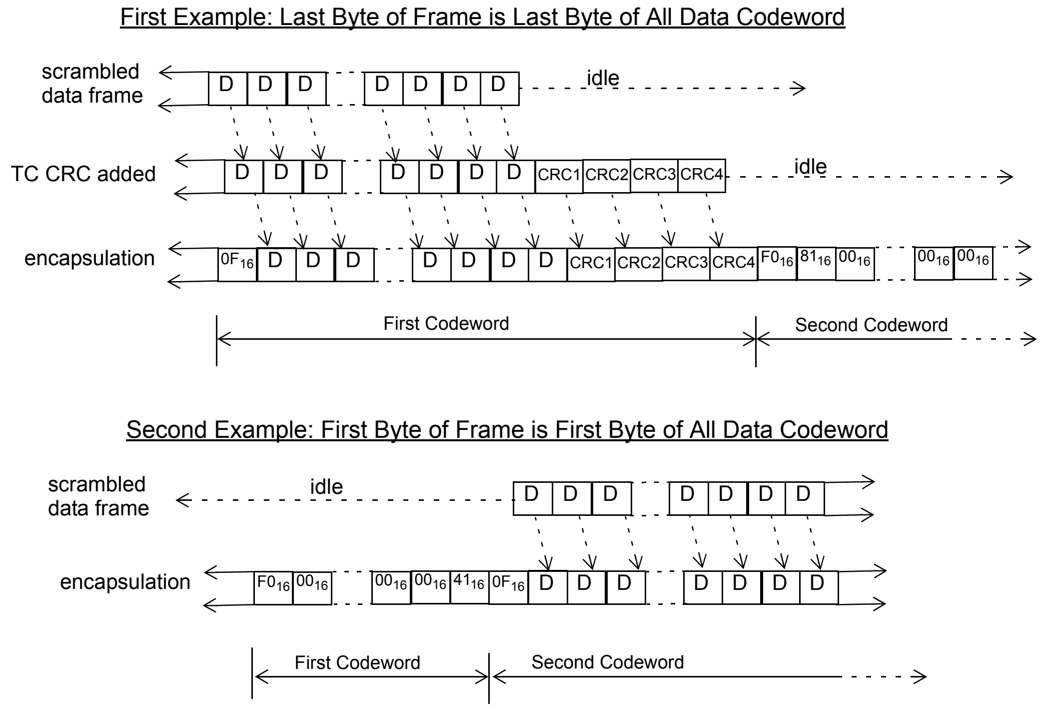

Figure 61–17—TC Encapsulation examples

The values of the byte fields are shown in Table 61–10. The byte value *E* is used to signify the end of a frag-

Table 61–10—TC encapsulation fields

Codeword Type	Character	Value
All data frames	D_n	00-FF_{16}
Idle, start or end frames	Z	00_{16}
End of frame or end/start frame	C_n, n=0-63	C_n = n+1+[even parity bit in position d7]; $C_0=81_{16}$, $C_1=82_{16}$, $C_2=03_{16}$, ... $C_{62}=3F_{16}$, $C_{63}=C0_{16}$
Start of Frame or end/start frame	S	41_{16}
End of Errored Frame	E	$C2_{16}$

ment that is to be regarded by the receiver as in error. It is used when, during the tranmsmission of the fragment across the γ interface, the TX_Err signal is asserted. It serves to terminate the fragment immediately, in a manner equivalent to C_0 in that the next fragment may start with an *S* byte anytime subsequently during the codeword, with the difference that it marks the terminated frame as being erroneous.

61.2.3.3.4 Sync insertion and transmit control

The transmit data path needs a 64 stage pipeline in order to generate the appropriate sync byte along with an end-of-frame indicator when required. The flow control signal, Tx_Enbl, is used to slow the flow of data across the gamma interface to cater for the difference in clock speed between the alpha/beta and gamma interfaces and also to allow for the insertion of sync bytes and CRC codes into the data stream.

A simple implementation may use a 64 bit pipeline for the Tx_EOP control signal. In that case, an end of frame sync code ($F0_{16}$, then C_k) would be inserted whenever a bit is set in stages 63 to 1 of the pipeline (stage 64 is the first stage). The value of C_k inserted would be equal to the stage number of the bit that is set.

Note that some implementations may optimize the insertions of idles between frames. In particular an implementation may remove idle characters between frames to increase the effective bandwith of the channel.

61.2.3.3.5 CRC functions

The CRC is generated for the entire payload frame and any attached header (from PAF), including the Ethernet CRC; i.e., the CRC is computed over bytes from the first byte of the PAF header (if present), or the first byte of the DestinationAddress (in the case where the PAF header not present), to the last byte of the Ethernet CRC, inclusive. The CRC is added to the data stream after the end of the frame in the egress direction. The CRC is checked against the last 4 bytes of the frame in the ingress direction. If the ingress CRC is incorrect then Rx_Err is asserted to signal that the frame is errored.

The frame check sequence (FCS) contains a 4-octet (32-bit) cyclic redundancy check (CRC) value. This value is computed as a function of the contents of the entire payload frame, including Ethernet FCS. The encoding is defined by the following generating polynomial.

$$x^{32} + x^{28} + x^{27} + x^{26} + x^{25} + x^{23} + x^{22} + x^{20} + x^{19} + x^{18} + x^{14} + x^{13} + x^{11} + x^{10} + x^{9} + x^{8} + x^{6} + 1 = (x + 1)(x^{31} + x^{30} + x^{29} + x^{28} + x^{26} + x^{24} + x^{23} + x^{22} + x^{18} + x^{13} + x^{10} + x^{8} + x^{5} + x^{4} + x^{3} + x^{2} + x + 1) \quad (2)$$

Mathematically, the CRC value corresponding to a given payload frame (including any attached header) is defined by the following procedure:

a) The first 32 bits of the payload are complemented.
b) The n bits of the payload are then considered to be the coefficients of a polynomial M(x) of degree n–1. (The first bit of the PAF Header corresponds to the x(n–1) term and the last bit of the Ethernet FCS corresponds to the x^0 term.)
c) M(x) is multiplied by x^{32} and divided by G(x), the CRC polynomial, producing a remainder R(x) of degree =31.
d) The coefficients of R(x) are considered to be a 32-bit sequence.
e) The bit sequence is complemented and the result is the CRC.

The 32 bits of the CRC value are placed so that the x^{31} term is the leftmostbit of the first octet, and the x^0 term is the right most bit of the last octet. (The bits of the CRC are thus transmitted in the order x^{31}, x^{30},.., x^1, x^0).

At the receiver, a payload received without error will result in the remainder $1C2D19ED_{16}$ when divided by G(x).

61.2.3.3.6 Sync detection

The sync detection function serves two purposes. Firstly the syncronization shall be acquired from the incoming data stream, the sync detection function controls the initial acquisition and maintenance of the syncronization. Secondly, the sync detection is needed so that the receive control state machine can extract framing information from the ingress data stream and remove the sync characters and CRC codes. The sync detection state machine is shown in Figure 61–18.

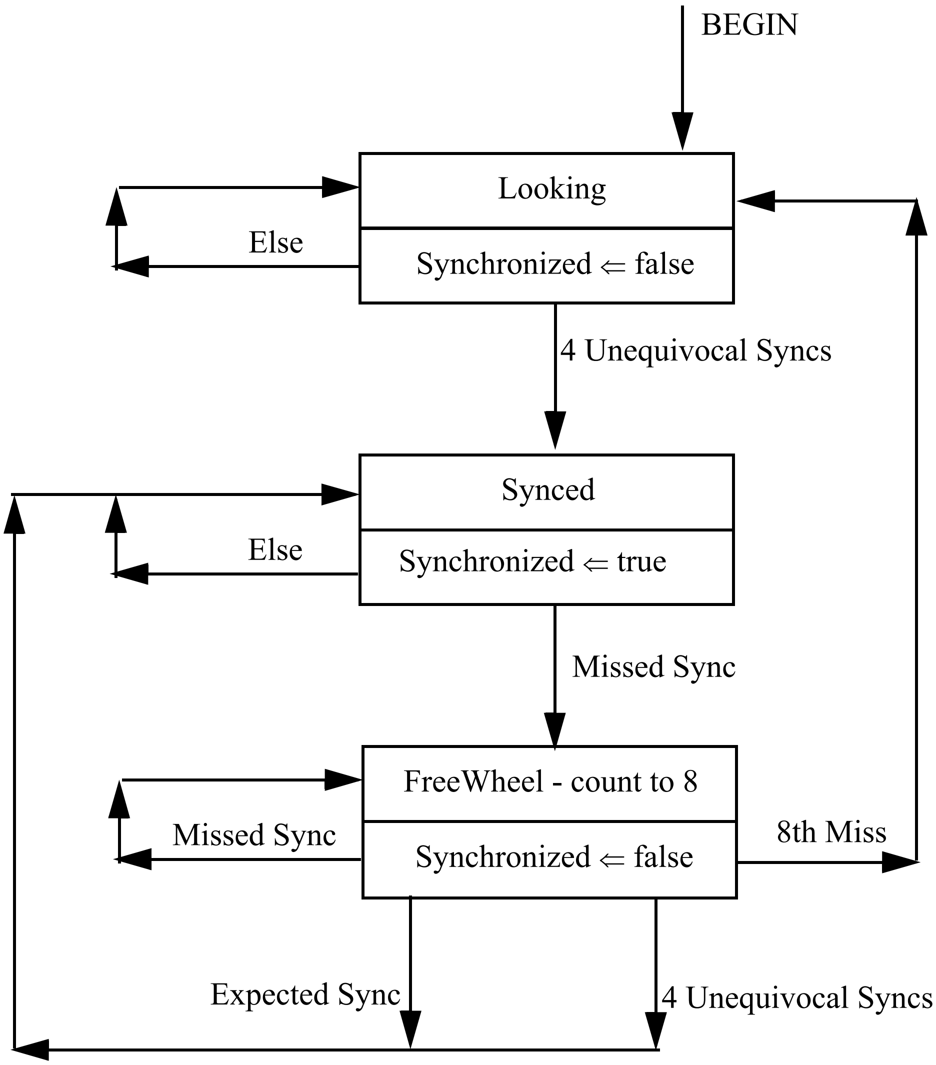

Figure 61–18—sync detect state machine

The definition of the state transition conditions is as follows:

a) 4 Unequivocal Syncs is defined as 4 consecutive syncs detected with no alternative sequence of more than 2 syncs during the same period.
b) Missed Sync is defined as a non-sync character in the byte stream position where a sync character is expected.
c) Expected Sync is defined as a sync character in the correct position in the byte stream
d) 8th Miss is defined as the 8^{th} consecutive occurrence of a non-sync character in the byte stream where sync characters are expected.

61.2.3.3.7 Receive control

The receive control function removes the sync characters and encapsulation CRC bytes from the data stream and descrambles it before it is passed upward across the γ interface. If Synchronized = false then signal RX_Enbl shall be de-asserted. If a CRC error is detected, or the fragment ends with a codeword with the *E* (errored) parameter (rather than a C_n), then the receive controller shall assert signal RX_Err during at least one byte of the fragment as it is passed up across the γ interface. The receive controller shall assert signal RX_Err during at least one byte of a fragment as it is passed up across the γ interface, if the fragment contains data from a block in data in which the PMA detected errors, but did not correct them (the menas by which the PHY passes this information from the PMA to the TC is unspecified).

61.2.3.3.8 TC sublayer: Management entity signals

The TC sublayer provides the following Management Entity primitives:

TC_loss_of_sync: this primitive is asserted to indicate that the synchronization state machine has detected a corrupted sync code and is freewheeling.

TC_CRC_error: this primitive is asserted to indicate that the synchronization state machine has detected a false CRC code for a received frame.

61.3 Handshaking and PHY control specification for type 2BASE-TL and 10PASS-TS

61.3.1 Overview

This subclause defines the startup and handshaking procedures by incorporating G.994.1 by reference. The G.994.1 parameter values and options to be used by 2BASE-TL and 10PASS-TS are specified here.

61.3.1.1 Scope: reference G.994.1 section 1 Scope, with changes shown

This subclause defines signals, messages, and procedures for exchanging these between 2BASE-TL and 10PASS-TS port types, when the modes of operation of the equipment need to be automatically established and selected, but before signals are exchanged which are specific to a particular port type.

The startup procedures defined here are compatible with those used by other equipment on the public access network, such as DSL transceivers compliant with ITU-T Recommendations. For interrelationships of this subclause with ITU-T G.99x-series Recommendations, see Recommendation G.995.1 (informative).

The principal characteristics of this subclause are as follows:

a) use over metallic local loops;

b) provisions to exchange capabilities information between DSL equipment and EFM PHYs to identify common modes of operation;

c) provisions for equipment at either end of the loop to select a common mode of operation or to request the other end to select the mode;

d) provisions for exchanging non-standard information between equipment;

e) provisions to exchange and request service and application related information;

f) support for both duplex and half-duplex transmission modes;

g) support for multi-pair operation;

h) provisions for equipment at the remote end of the loop (xTU-R) to propose a common mode of operation

61.3.1.2 Purpose

It is the goal of the ITU-T that all specifications for digital tranceivers for use on public telephone network copper subscriber lines use G.994.1 for startup. G.994.1 procedures allow for a common mechanism for identification of available features, exchange of capabilities and configuration information, and selection of operating mode. As the two loop endpoints are usually separated by a large distance (e.g., in separate buildings) and often owned and installed by different entities, G.994.1 also aids in diagnosing interoperability problems. G.994.1 codespaces have been assigned by ITU-T to ATIS, ETSI, and IEEE 802.3 in support of this goal.

61.3.2 References: reference G.994.1 section 2, References

Stet.

61.3.3 Definitions: reference G.994.1 section 3, Definitions

Stet.

61.3.3.1 Acronyms and abbreviations: reference G.994.1 section 4, Abbreviations

Stet.

61.3.4 System reference diagram: reference G.994.1 section 5

All Paragraphs: Stet.

61.3.5 Signals and modulation

61.3.5.1 Description of signals: reference G.994.1 section 6.1

All Paragraphs prior to NOTE 4: Stet.

NOTE 4 – Not Applicable.

NOTE 5 – Not Applicable.

61.3.5.1.1 4.3125 kHz signalling family: reference G.994.1 section 6.1.1

Paragraph 1: Stet.

Paragraph 2: Stet.

Paragraph 3: The carrier sets in this family are mandatory for the port types listed in Table 61–12. One or more carriers listed in Table 61–11, Table 61–13, Reference Table 1 or Reference Table 3 may be transmitted in addition to the mandatory carrier set listed in Table 61–12. Carriers not listed in Table 61–11, Table 61–13, Reference Table 1 or Reference Table 3 shall not be transmitted..

Editor's Note: Carrier set B43 applies to MCM-VDSL only.

61.3.5.1.2 4 kHz signalling family: reference G.994.1 section 6.1.2

Paragraph 1: Stet.

Paragraph 2: Stet.

Table 61–11—Carrier sets for the 4.3125 kHz signalling family

Carrier set designation	Upstream carrier sets		Downstream carrier sets		Transmission mode
	Frequency indices (N)	Maximum power level/carrier (dBm)	Frequency indices (N)	Maximum power level/carrier (dBm)	
B43	37; 45; 53	-1.65	72; 88; 96	-3.65	duplex only

Table 61–12—Mandatory carrier sets

Port Types	Carrier set designation
10PASS-TS	B43

Paragraph 3: The carrier sets in this family are mandatory for the port types listed in Table 61–14. One or more carriers listed in Reference Table 61–11, Table 61–13, Reference Table 1 or Reference Table 3 may be transmitted in addition to the mandatory carrier set listed in Table 61–12. Carriers not listed in Table 61–11, Table 61–13, Reference Table 1 or Reference Table 3 shall not be transmitted.

Table 61–13—Carrier sets for the 4 kHz signalling family

Carrier set designation	Upstream carrier sets		Downstream carrier sets		Transmission mode
	Frequency indices (N)	Maximum power level/carrier (dBm)	Frequency indices (N)	Maximum power level/carrier (dBm)	
A4	3	+5	5	+5	half-duplex only
B4	44; 66	-5	64; 96	-5	half-duplex only

Table 61–14—Mandatory carrier sets

Port Types	Carrier set designation
2BASE-TL	A4
10PASS-TS	B4

Editor's Note: Carrier set B4 applies to SCM-VDSL only.

61.3.5.2 Modulation: reference G.994.1 section 6.2

Stet.

61.3.5.3 Transmit filter characteristics: reference G.994.1 section 6.3

61.3.5.3.1 4.3125 kHz signalling family: reference G.994.1 section 6.3.1

Stet.

61.3.5.3.2 4 kHz signalling family: reference G.994.1 section 6.3.2

Stet.

61.3.6 Description of messages: reference G.994.1 section 7, including all subsections

Stet.

61.3.7 Structure of messages: reference G.994.1 section 8, including all subsections

Stet.

61.3.8 Message coding format: reference G.994.1 section 9

61.3.8.1 General: reference G.994.1 section 9.1

Stet.

61.3.8.2 Coding format for parameters in the I and S fields: reference G.994.1 section 9.2

Stet.

61.3.8.3 Parameter classification: reference G.994.1 section 9.2.1

Stet.

61.3.8.4 Order of transmission of parameters: reference G.994.1 section 9.2.2

Stet.

61.3.8.5 Delimiting and parsing of parameter blocks: reference G.994.1 section 9.2.3

Stet.

61.3.8.6 Identification field (I): reference G.994.1 section 9.3

Stet.

61.3.8.6.1 Message type: reference G.994.1 section 9.3.1

Stet.

61.3.8.6.2 Revision number: reference G.994.1 section 9.3.2

Stet.

Additional Paragraph: Equipment indicating 2BASE-TL or 10PASS-TS functionality shall indicate Revision Number 2.

61.3.8.6.3 Vendor ID field: reference G.994.1 section 9.3.3

Stet.

61.3.8.6.4 Parameter field: reference G.994.1 section 9.3.4

Paragraph 1: Stet.

Paragraph 2: Stet.

Paragraph 3: Stet.

Paragraph 4: The NPars and SPars used by 2BASE-TL and 10PASS-TS Ports are listed below, beginning with Table 61–15.

Table 61–15—Identification field – NPar(1) coding

Bits								NPar(1)s
8	7	6	5	4	3	2	1	
x	0	0	0	0	0	0	0	No parameters set in this octet

Tables 9.15-9.31/G.994.1 – Identification field – Relative power level/carrier –

Table 61–16— Identification field – SPar(1) coding – Octet 1

Bits								SPar(1)s
8	7	6	5	4	3	2	1	
x	0	0	0	0	0	0	0	No parameters set in this octet

NPar(2) coding

Editor's Note: The use of the bits in these tables in EFM is TBD

61.3.8.7 Standard information field (S): reference G.994.1 section 9.4

Subclause Editor's Note: Philosophy of S Field coding. I propose here to assign a Level 1 bit for each of the two port types ITU-T Q4/15 has agreed to reserve two such bits. This puts the two EFM port types at the same level in the G.994.1 hierarchy as the transceiver standards from ITU-T, ATIS T1, and ETSI.

Editor's Note: At the time of writing D1.414, it is not certain which G.994.1 bits will be assigned to EFM/Copper PHYs; this is a technical issue that needs to be resolved prior to WG ballot.

Paragraphs 1-5: Stet.

Table 61–17—Identification field – SPar(1) coding – Octet 2

Bits								SPar(1)s – Octet 2
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Relative power level/carrier for upstream carrier set A43[a]
x	x	x	x	x	x	1	x	Relative power level/carrier for downstream carrier set A43*
x	x	x	x	x	1	x	x	Relative power level/carrier for upstream carrier set B43*
x	x	x	x	1	x	x	x	Relative power level/carrier for downstream carrier set B43*
x	x	x	1	x	x	x	x	Relative power level/carrier for upstream carrier set C43*
x	x	1	x	x	x	x	x	Relative power level/carrier for downstream carrier set C43*
x	1	x	x	x	x	x	x	Reserved for allocation by the ITU-T
x	0	0	0	0	0	0	0	No parameters in this octet

[a]The relative power level/carrier reported in a CLR, CL, MP, or MS message indicates the level used during the current G.994.1 session, including the start-up and cleardown procedures. It does not imply any requirements on the transmit power in this or future sessions.
Subclause Editor's Note: The use of these bits in EFM is TBD

Table 11.1 to Table 11.39: Not Applicable

Table 61–18—Standard information field – NPar(1) coding

Bits								NPar(1)s
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Voiceband: V.8[a]
x	x	x	x	x	x	1	x	Voiceband: V.8 *bis**
x	x	x	x	x	1	x	x	Silent period[b]
x	x	x	x	1	x	x	x	G.997.1[c]
x	x	x	1	x	x	x	x	Reserved for allocation by the ITU-T
x	x	1	x	x	x	x	x	Reserved for allocation by the ITU-T
x	1	x	x	x	x	x	x	Reserved for allocation by the ITU-T
x	0	0	0	0	0	0	0	No parameters in this octet

[a]Setting this bit to binary ONE in an MS message initiates the G.994.1 session cleardown procedure specified in 11.3, and requests a V.8 or V.8 *bis* handshake in the voiceband, with the xTU-R taking on the role of a calling station and the xTU-C taking on the role of an answering station.

[b]This bit shall be set to binary ONE in a CLR or CL message. Setting this bit to binary ONE in an MS message initiates the G.994.1 session cleardown procedure specified in 11.3, and requests a silence period at the other transmitter of approximately 1 minute. The station that invoked the silent period by transmitting MS may terminate the silent period prior to the 1 minute by restarting a G.994.1 session.
[c]The use of this bit is for further study and shall be set to binary ZERO in CLR, CL and MS.
Editor's Note: The use of these bits in EFM is TBD

Table 61–19—Standard information field – SPar(1) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	SPar(1)s – Octet 1
x	1	x	x	x	x	x	x	2BASE-TL[a]
x	0	0	0	0	0	0	0	No parameters in this octet

[a]*Editor's Note: Final allocation of this bit is pending agreement with ITU-T*

Table 61–20—Standard information field – SPar(1) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	SPar(1)s – Octet 2
x	1	x	x	x	x	x	x	10PASS-TS[a]
x	0	0	0	0	0	0	0	No parameters in this octet

[a]*Editor's Note: Final allocation of thi bits is pending agreement with ITU-T*

Table 61–21—Standard information field – 10PASS-TS NPar(2) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS NPar(2)s
x	x	x	x	x	x	x	1	Band A
x	x	x	x	x	x	1	x	Band B
x	x	x	x	x	1	x	x	Band C
x	x	x	x	1	x	x	x	Upstream use of 25-138 KHz band
x	x	x	1	x	x	x	x	Downstream use of 25-138 KHz band
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Editor's note:The 10PASS-TS Tables assume that most of the MCM options specified in Levels 2 and 3 of the Committee T1 standard (e.g., Clear EOC, cyclic extension length, RFI

Table 61–22—Standard information field – 10PASS-TS NPar(2) coding – Octet 2

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(2)s**
x	x	x	x	x	x	x	1	SCM PMD (10PASS-TS/QAM)
x	x	x	x	x	x	1	x	MCM PMD (10PASS-TS/DMT)
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

bands, etc.), will be fixed (either mandatory or unused) in EFM, and thus do not need to be specified here. For those parameters that are still being studied, messages will be defined.

Editor's Note: The following tables for 2BASE-TL are derived from G.994.1 tables for

Table 61–23—Standard information field – 10PASS-TS SPar(2) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS SPar(2)s
x	x	x	x	x	x	x	1	PMI Aggregation Discovery
x	x	x	x	x	x	1	x	Reserved for allocation by IEEE 802.3
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–24—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS NPar(3)s - Octet 1
x	x	x	x	x	x	x	1	Clear if same
x	x	x	x	x	x	1	x	Reserved for allocation by IEEE 802.3
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–25—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 2

Bits 8	7	6	5	4	3	2	1	10PASS-TS NPar(3)s - Octet 2
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 48 to 43

G.991.2. Note, however, these are new tables to be added to the G.994.1 tree.

Table 61–26—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 3

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 3**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 42 to 37

Table 61–27—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 4

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 4**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 36 to 31

Table 61–28—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 5

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 5**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 30 to 25

Table 61–29—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 6

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 6**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 24 to 19

Table 61–30—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 7

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 7**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 18 to 13

Editor's Note: Bits from Table 11.30.0.2 and 11.30.0.3 not needed, as EFM path is always 64B/65B.

Table 61–31—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 8

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 8**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 12 to 7

Table 61–32—Standard information field – 10PASS-TS NPar(3) coding - PMI Aggregation Discovery– Octet 9

Bits								
8	7	6	5	4	3	2	1	**10PASS-TS NPar(3)s - Octet 9**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 6 to 1

Table 61–33—Standard information field – 2BASE-TL - NPar(2) coding – Octet 1

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(2)s - Octet 1**
x	x	x	x	x	x	x	1	2BASE-TL Training mode[a]
x	x	x	x	x	x	1	x	2BASE-TL PMMS mode*
x	x	x	x	x	1	x	x	2BASE-TL Band A Operation
x	x	x	x	1	x	x	x	2BASE-TL Band B Operatiuon
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

[a]Only one of these bits shall be set at any given time.

Editor's Note: Only one latency path in EFM, so the fSPAR(2) octets from Tables 11.30.0.4-11.30.0.9 are not needed

61.3.8.8 Non-standard information field (NS): reference G.994.1 section 9.5

Add this paragraph: The contents of the NS informtion field are outside the scope of this Standard.

Stet.

Table 61–34—Standard information field – 2BASE-TL - SPar(2) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL SPar(2)s – Octet 1
x	x	x	x	x	x	x	1	2BASE-TL Downstream training parameters
x	x	x	x	x	x	1	x	2BASE-TL Upstream training parameters
x	x	x	x	x	1	x	x	2BASE-TL Downstream PMMS parameters
x	x	x	x	1	x	x	x	2BASE-TL Upstream PMMS parameters
x	x	x	1	x	x	x	x	2BASE-TL Downstream framing parameters[a]
x	x	1	x	x	x	x	x	2BASE-TL Upstream framing parameters
x	x	0	0	0	0	0	0	No parameters in this octet

[a] *Editor's note: This assumes TPS-TC parameters will be fixed for EFM. Also, if Sync Words and Stuff bits are fixed for EFM, framing parameter Npar(3) fields will not be needed.*

Table 61–35—Standard information field – 2BASE-TL SPar(2) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL SPar(2)s – Octet 4
x	x	x	x	x	x	x	1	PMI Aggregation Discovery
x	x	x	x	x	x	1	x	Reserved for allocation by IEEE 802.3
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–36—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Downstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61–37—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 2

Bits								2BASE-TL downstream training NPar(3)s – Octet 2
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Downstream base data rate unspecified by terminal
x	x	x	x	x	x	1	x	Reserved for allocation by IEEE 802.3
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Downstream base data rate = 192 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 256 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–38—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 3

Bits								2BASE-TL downstream training NPar(3)s – Octet 3
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Downstream base data rate = 320 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 384 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 448 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 512 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 576 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 640 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

61.3.8.9 Overall message composition: reference G.994.1 section 9.6

Stet.

Table 61–39—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 4
x	x	x	x	x	x	x	1	Downstream base data rate = 704 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 768 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 832 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 896 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 960 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 1.024 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–40—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 5

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 5
x	x	x	x	x	x	x	1	Downstream base data rate = 1.088 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 1.152 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 1.216 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 1.280 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 1.344 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 1.408 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–41—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 6

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s Octet 6
x	x	x	x	x	x	x	1	Downstream base data rate = 1.472 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 1.536 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 1.600 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 1.664 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 1.728 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 1.792 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–42—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 7

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 7
x	x	x	x	x	x	x	1	Downstream base data rate = 1.856 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 1.920 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 1.984 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 2.048 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 2.112 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 2.176 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–43—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 9

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 9
x	x	x	x	x	x	x	1	Downstream sub data rate = 0 kbit/s
x	x	x	x	x	x	1	x	Downstream sub data rate = 8 kbit/s
x	x	x	x	x	1	x	x	Downstream sub data rate = 16 kbit/s
x	x	x	x	1	x	x	x	Downstream sub data rate = 24 kbit/s
x	x	x	1	x	x	x	x	Downstream sub data rate = 32 kbit/s
x	x	1	x	x	x	x	x	Downstream sub data rate = 40 kbit/s
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–44— Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 10

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 10
x	x	x	x	x	x	x	1	Downstream sub data rate = 48 kbit/s
x	x	x	x	x	x	1	x	Downstream sub data rate = 56 kbit/s
x	x	x	x	x	1	x	x	Downstream sub data rate unspecified by terminal
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–45—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Upstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61–46—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 2
x	x	x	x	x	x	x	1	Upstream base data rate unspecified by terminal
x	x	x	x	x	x	1	x	Reserved for allocation by IEEE 802.3
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Upstream base data rate = 192 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 256 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–47—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 3
x	x	x	x	x	x	x	1	Upstream base data rate = 320 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 384 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 448 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 512 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 576 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 640 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

61.3.9 G.994.1 transactions: reference G.994.1 section 10, including subsections

Stet.

Table 61–48—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 4
x	x	x	x	x	x	x	1	Upstream base data rate = 704 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 768 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 832 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 896 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 960 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 1.024 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–49—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 5

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 5
x	x	x	x	x	x	x	1	Upstream base data rate = 1.088 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 1.152 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 1.216 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 1.280 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 1.344 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 1.408 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–50—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 6

Bits								2BASE-TL Upstream training NPar(3)s Octet 6
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Upstream base data rate = 1.472 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 1.536 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 1.600 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 1.664 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 1.728 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 1.792 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–51—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 7

Bits								2BASE-TL Upstream training NPar(3)s – Octet 7
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Upstream base data rate = 1.856 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 1.920 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 1.984 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 2.048 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 2.112 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 2.176 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–52—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 8

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 8
x	x	x	x	x	x	x	1	Upstream base data rate = 2.240 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 2.304 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–53—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 9

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream training NPar(3)s – Octet 9
x	x	x	x	x	x	x	1	Upstream sub data rate = 0 kbit/s
x	x	x	x	x	x	1	x	Upstream sub data rate = 8 kbit/s
x	x	x	x	x	1	x	x	Upstream sub data rate = 16 kbit/s
x	x	x	x	1	x	x	x	Upstream sub data rate = 24 kbit/s
x	x	x	1	x	x	x	x	Upstream sub data rate = 32 kbit/s
x	x	1	x	x	x	x	x	Upstream sub data rate = 40 kbit/s
x	x	0	0	0	0	0	0	No parameters in this octet

61.3.10 Start-up/cleardown procedures: reference G.994.1 section 11

61.3.10.1 Duplex start-up procedures: reference G.994.1 section 11.1

Stet.

61.3.10.2 Half-duplex start-up procedures: reference G.994.1 section 11.2

Stet.

Subclause Editor's note: Whether to permit half-duplex startup for EFM is TBD.

Table 61–54— Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 10

Bits								2BASE-TL Upstream training NPar(3)s – Octet 10
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Upstream sub data rate = 48 kbit/s
x	x	x	x	x	x	1	x	Upstream sub data rate = 56 kbit/s
x	x	x	x	x	1	x	x	Upstream sub data rate unspecified by terminal
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–55—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 1

Bits								2BASE-TL downstream PMMS NPar(3)s – Octet 1
8	7	6	5	4	3	2	1	
x	x	0	x	x	x	x	x	Downstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61–56—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 2

Bits								2BASE-TL downstream PMMS NPar(3)s – Octet 2
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Downstream base data rate unspecified by terminal
x	x	x	x	x	x	1	x	Transmit Silence
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Downstream base data rate = 192 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 256 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–57—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 3
x	x	x	x	x	x	x	1	Downstream base data rate = 320 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 384 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 448 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 512 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 576 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 640 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–58—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 4
x	x	x	x	x	x	x	1	Downstream base data rate = 704 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 768 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 832 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 896 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 960 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 1.024 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–59—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 5

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 5
x	x	x	x	x	x	x	1	Downstream base data rate = 1.088 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 1.152 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 1.216 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 1.280 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 1.344 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 1.408 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–60—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 6

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s Octet 6
x	x	x	x	x	x	x	1	Downstream base data rate = 1.472 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 1.536 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 1.600 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 1.664 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 1.728 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 1.792 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–61—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 7

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 7
x	x	x	x	x	x	x	1	Downstream base data rate = 1.856 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 1.920 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Downstream base data rate = 1.984 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Downstream base data rate = 2.048 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Downstream base data rate = 2.112 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Downstream base data rate = 2.176 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–62—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 8

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 8
x	x	x	x	x	x	x	1	Downstream base data rate = 2.240 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Downstream base data rate = 2.304 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

61.3.10.3 Cleardown procedure: reference G.994.1 section 11.3

Stet.

Table 61–63—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 9

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 9
x	x	0	0	0	0	0	0	Downstream PMMS duration unspecified by terminal
x	x	x	x	x	x	x	x	Downstream PMMS duration (bits 6-1 x 50 ms)
x	x	1	1	1	1	1	1	Reserved for allocation by IEEE 802.3

Table 61–64—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 10

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 10
x	x	0	0	0	0	0	0	Downstream PMMS scrambler polynomial Index (i2, i1, i0)
x	x	1	1	1	1	1	1	Reserved for allocation by IEEE 802.3

Table 61–65—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 11

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 11
x	x	1	x	x	x	x	x	Worst-case PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–66—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 12

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 12
x	x	1	x	x	x	x	x	Current-condition PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–67—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream PMMS NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Upstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61–68—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream PMMS NPar(3)s – Octet 2
x	x	x	x	x	x	x	1	Upstream base data rate unspecified by terminal
x	x	x	x	x	x	1	x	Transmit Silence
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Upstream base data rate = 192 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 256 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

61.3.11 Error recovery procedures: reference G.994.1 section 12

Stet.

Annex A / G.994.1 - Support for legacy non-G.994.1 devices - not applicable

Annex B / G.994.1 - operation over multiple wire pairs - not applicable to the multipair operation for EFM

Appendix I / G.994.1 - not applicable

Appendix II / G.994.1 - Provider Code contact Information - Stet.

Appendix III / G.994.1 - support for legacy DMT-based devices - not applicable

Appendix IV / G.994.1 - Procedure for the assignment of additional G.994.1 parameters - not applicable

Appendix V / G.994.1 - Rules for code point table numbering - not applicable

Appendix VI / G.994.1 - Bibliography

Table 61–69—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream PMMS NPar(3)s – Octet 3
x	x	x	x	x	x	x	1	Upstream base data rate = 320 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 384 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 448 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 512 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 576 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 640 kbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–70—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream PMMS NPar(3)s – Octet 4
x	x	x	x	x	x	x	1	Upstream base data rate = 704 kbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 768 kbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 832 kbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 896 kbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 960 kbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 1.024 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–71—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 5

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream PMMS NPar(3)s – Octet 5
x	x	x	x	x	x	x	1	Upstream base data rate = 1.088 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 1.152 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 1.216 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 1.280 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 1.344 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 1.408 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–72—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 6

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream PMMS NPar(3)s Octet 6
x	x	x	x	x	x	x	1	Upstream base data rate = 1.472 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 1.536 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 1.600 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 1.664 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 1.728 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 1.792 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–73—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 7

Bits								2BASE-TL Upstream PMMS NPar(3)s – Octet 7
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Upstream base data rate = 1.856 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 1.920 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Upstream base data rate = 1.984 Mbit/s, symmetric PSD
x	x	x	x	1	x	x	x	Upstream base data rate = 2.048 Mbit/s, symmetric PSD
x	x	x	1	x	x	x	x	Upstream base data rate = 2.112 Mbit/s, symmetric PSD
x	x	1	x	x	x	x	x	Upstream base data rate = 2.176 Mbit/s, symmetric PSD
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–74—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 8

Bits								2BASE-TL Upstream PMMS NPar(3)s – Octet 8
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	Upstream base data rate = 2.240 Mbit/s, symmetric PSD
x	x	x	x	x	x	1	x	Upstream base data rate = 2.304 Mbit/s, symmetric PSD
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–75—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 9

Bits								2BASE-TL Upstream PMMS NPar(3)s – Octet 9
8	7	6	5	4	3	2	1	
x	x	0	0	0	0	0	0	Upstream PMMS duration unspecified by terminal
x	x	x	x	x	x	x	x	Upstream PMMS duration (bits 6-1 x 50 ms)
x	x	1	1	1	1	1	1	Reserved for allocation by IEEE 802.3

Table 61–76—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 10

Bits								2BASE-TL Upstream PMMS NPar(3)s – Octet 10
8	7	6	5	4	3	2	1	
x	x	0	0	0	0	0	0	Upstream PMMS scrambler polynomial Index (i2, i1, i0)
x	x	1	1	1	1	1	1	Reserved for allocation by IEEE 802.3

Table 61–77—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 11

Bits								2BASE-TL Upstream PMMS NPar(3)s – Octet 11
8	7	6	5	4	3	2	1	
x	x	1	x	x	x	x	x	Worst-case PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–78—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 12

Bits								2BASE-TL Upstream PMMS NPar(3)s – Octet 12
8	7	6	5	4	3	2	1	
x	x	1	x	x	x	x	x	Current-condition PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–79—Standard information field – 2BASE-TL - Downstream framing parameters - NPar(3) coding – Octet 1

Bits								2BASE-TL Downstream framing NPar(3)s – Octet 1
8	7	6	5	4	3	2	1	
x	x					x	x	Sync Word (bits 14 and 13)
x	x	x	x	x	x			Stuff Bits (bits 1 to 4)

Table 61–80—Standard information field – 2BASE-TL - Downstream framing parameters - NPar(3) coding – Octet 2

Bits								2BASE-TL Downstream framing NPar(3)s – Octet 2
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	x	Sync Word (bits 12 to 7)

Table 61–81—Standard information field – 2BASE-TL - Downstream framing parameters - NPar(3) coding – Octet 3

Bits								2BASE-TL Downstream framing NPar(3)s – Octet 3
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	x	Sync Word (bits 6 to 1)

Table 61–82—Standard information field – 2BASE-TL - Upstream framing parameters - NPar(3) coding – Octet 1

Bits								2BASE-TL Upstream framing NPar(3)s – Octet 1
8	7	6	5	4	3	2	1	
x	x					x	x	Sync Word (bits 14 and 13)
x	x	x	x	x	x			Stuff Bits (bits 1 to 4)

Table 61–83—Standard information field – 2BASE-TL - Upstream framing parameters - NPar(3) coding – Octet 2

Bits								2BASE-TL Upstream framing NPar(3)s – Octet 2
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	x	Sync Word (bits 12 to 7)

Table 61–84—Standard information field – 2BASE-TL - Upstream framing parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream framing NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Sync Word (bits 6 to 1)

Table 61–85—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL NPar(3)s - Octet 1
x	x	x	x	x	x	x	1	Clear if same
x	x	x	x	x	x	1	x	Reserved for allocation by IEEE 802.3
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61–86—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL NPar(3)s - Octet 2
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 48 to 43

Table 61–87—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL NPar(3)s - Octet 3
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 42 to 37

Table 61–88—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 4

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(3)s - Octet 4**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 36 to 31

Table 61–89—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 5

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(3)s - Octet 5**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 30 to 25

Table 61–90—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 6

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(3)s - Octet 6**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 24 to 19

Table 61–91—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 7

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(3)s - Octet 7**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 18 to 13

Table 61–92—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 8

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(3)s - Octet 8**
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 12 to 7

Table 61–93—Standard information field – 2BASE-TL NPar(3) coding - PMI Aggregation Discovery– Octet 9

Bits								2BASE-TL NPar(3)s - Octet 9
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	1	PMI Aggregation register, bits 6 to 1

61.4 PMA service interface

61.5 Link segment characteristics

61.6 MDI specification

61.7 System considerations

61.8 Environmental specifications

61.9 PHY labeling

61.10 Timing summary

61.11 Protocol Implementation Conformance Statement (PICS) proforma for Clause 61, Physical Coding Sublayer (PCS) type 10PASS-TS, 2BASE-TL

61.11.1 Introduction

61.11.2 Identification

61.11.2.1 Implementation identification

61.11.2.2 Protocol summary

61.11.3 Major capabilities/options

61.11.4 PICS proforma tables for the Physical Coding Sublayer (PCS) type 10PASS-TS, 2BASE-TL

62. Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS

Editors' Notes: *To be removed prior to final publication.*

References:

T1.417
T1.424/Trial-Use Part 1
T1.424/Trial-Use Part 2
T1.424/Trial-Use Part 3
G.993.1
TS 101 270-1, 270-2

Definitions (to be added to 1.4):

None

Abbreviations (to be added to 1.5):

DMT: Discrete Multi-Tone
QAM: Quadrature Amplitude Modulation
PMS-TC: Physical Media Specific - Transmission Convergence
VTU-O: VDSL Transceiver Unit -CO side (10PASS-TS-O)
VTU-R: VDSL Transceiver Unit - CPE side (10PASS-TS-R)
LT: Line Termination (10PASS-TS-O, 2BASE-TL-O)
NT: Network Termination (10PASS-TS-R, 2BASE-TL-R)

Revision History:

Draft 0.9	June 2002	Preliminary draft outline for IEEE P802.3ah Task Force review.
Draft 1.0	August 2002	Preliminary draft for IEEE P802.3ah Task Force review
Draft 1.1	October 2002	Draft for IEEE P802.3ah Task Force review
Draft 1.2	November 2002	Draft for IEEE P802.3ah Task Force review
Draft 1.3	January 2003	Draft for IEEE P802.3ah Task Force review
Draft 1.414	April 2003	Draft for IEEE P802.3ah Task Force review. Incorporated last round of comments from March 2003 Plenary meeting.

62.1 Overview

Editor's note: Sections 62.2 and 62.3 (DMT PMA functional specifications and SCM PMA functional specifications) are mutually exclusive. Only one will be included in the final standard. Similarly, sections 62.4 and 62.5 (DMT PMD functional specifications and SCM PMD functional specifications) are mutually exclusive.

62.1.1 Scope

62.1.2 Objectives

The following are the objectives for 10PASS-TS:

a) To provide 10Mb/s encapsulated packet data rate at the α(β) interface.
b) To provide full duplex operation.
c) To provide for operating over non-loaded voice grade twisted pair cable at distances up to 750 m.
d) To provide a communication channel with a mean bit error rate, at the α(β) interface, of less than one part in 10^7 with 6 dB noise margin.

62.1.3 Relation of 10PASS-TS to other standards

The specifications of 10PASS-TS PMA and PMD are based on the VDSL transceiver specified in standard T1.424/Trial-Use.

62.1.4 Summary of Physical Medium Attachment (PMA) specification

This layer is defined by the α(β) interface and the I-interface.

62.1.4.1 α(β) Interface

A complete definition of the α(β) interface is contained in 61.2.3.2.

62.1.4.2 The I Interface

The I_O and I_R reference points define interfaces between the PMA and PMD in the 10PASS-TS-O and 10PASS-TS-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flows:

a) Data flow
b) Synchronization flow

62.1.4.2.1 The I Data Flow

The data flow consists of two octet-oriented streams, both with the PMA frame format, with the bit rates defined by the PMD transmission profile:

a) Transmitted data (Tx)
a) Received data (Rx).

If data streams are implemented serially, the MSB of each octet is sent first.

Each stream bit rate value is set during PMD configuration.

62.1.4.2.2 The I Synchronization Flow

The synchronization flow consists of the transmitted and received octet synchronization signals (Clko_t, Clko_r). Optional transmit and receive bit-synchronization signals (Clkp_t, Clkp_r) are defined too.

Synchronization signals are asserted by the PMD and directed towards the PMA.

The synchronization flow signals are described in Table 62–1.

Table 62–1—I Interface signals

Signal(s)	Description	Direction	Notes
Data Signals			
Tx	Transmitted data stream	PMA → PMD	Transmission frame format.
Rx	Received data stream	PMA ← PMD	
Synchronization Signals			
Clko_t	Transmitted octet timing	PMA ← PMD	
Clko_r	Received octet timing	PMA ← PMD	
Clkp_t	Transmitted bit timing	PMA ← PMD	Optional
Clkp_r	Received bit timing	PMA ← PMD	Optional

62.2 DMT PMA functional specifications

All data bytes shall be transmitted MSB first. All serial processing (e.g.: scrambling, CRC calculation) shall however be performed LSB first, with the outside world MSB considered as the VDSL LSB. As a result, the first incoming bit (outside world MSB) shall be the first bit processed inside VDSL (VDSL LSB).

62.2.1 DMT PMA functional diagram

Figure 62–1shows a diagram of the PMA sublayer.

62.2.2 PMA functional specifications

The 10PASS-TS PMA is specified by incorporating the MCM-VDSL standard, T1.424/Trial-Use Part 3, by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, T1.424/Trial-Use Part 3, will henceforth be referred to as MCM-VDSL.

62.2.3 General exceptions

The 10PASS-TS PMA is precisely the PMS-TC specified in MCM-VDSL, with the following general modifications:

a) There are minor terminology differences between this standard and MCM-VDSL that do not cause ambiguity. The terminology used in 10PASS-TS was chosen to be consistent with other IEEE 802 standards, rather than with MCM-VDSL. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 62–2.
b) The 10PASS-TS PMA does not support the “fast path”.

62.2.4 Specific requirements and exceptions

The 10PASS-TS PMA shall comply to the requirements of MCM-VDSL Section 9.3. Where there is conflict between specifications in MCM-VDSL and those in this standard, those of this standard shall prevail.

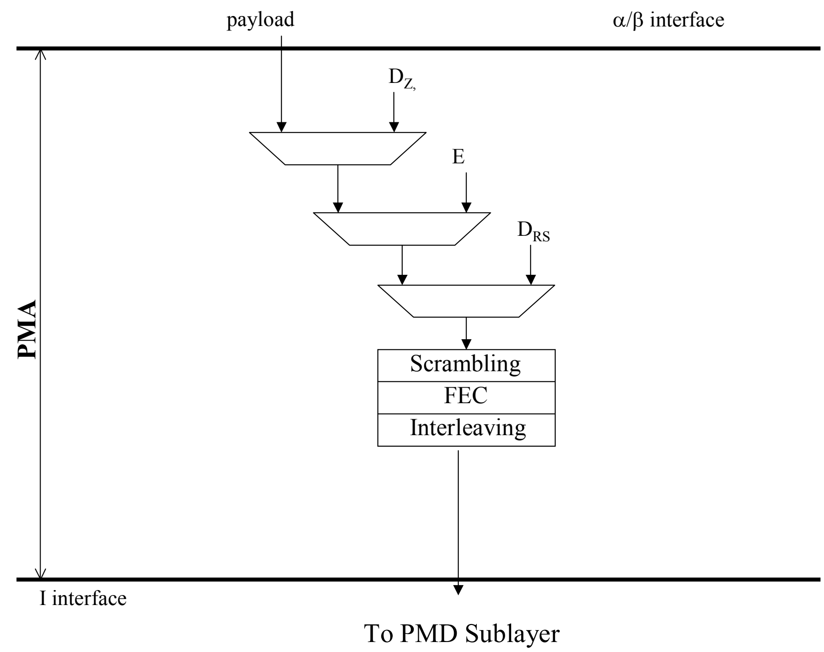

Figure 62–1—Diagram of PMA sublayer

Table 62–2—Interpretation of general MCM-VDSL terms and concepts

MCM-VDSL term or concept	Interpretation for 10PASS-TS
PMS-TC	PMA
VTU-O, LT	10PASS-TS-O
VTU-R, NT	10PASS-TS-R
Transmission medium dependent interface	MDI
U1-interface (splitter present)	
U2-interface (splitter absent)	

62.2.4.1 Reference section 9.3.1

9.3.1 of MCM-VDSL is replaced by the PMA functional diagram in 62.2.1.

62.2.4.2 Reference section 9.3.2

Stet.

62.2.4.3 Reference section 9.3.3

Stet, with the exception of TBD Reed-Solomon encoder settings.

62.2.4.4 Reference section 9.3.4

Stet.

62.2.4.5 Reference section 9.3.5

Stet, with following exceptions:

a) the “fast” buffer is not supported
b) 9.3.5.5.4 (NTR) is not applicable

62.3 SCM PMA functional specifications

The SCM PMA functionality is specified by incorporating the following references:

- Reference 1-1: T1.424/Trial-Use standard Part 1

- Reference 1-2: T1.424/Trial-Use standard Part 2

- Reference 2: ITU-T G.993.1

- Reference 3-1: ETSI TS 101 270-1

- Reference 3-2: ETSI TS 101 270-2

62.3.1 PMA Functional Block Diagram

The PMA sublayer includes functional blocks for randomization/de-randomization (Scrambler), forward error correction (FEC), interleaving, frame encapsulation (MUX) and management.

The PMA interfaces with the PCS sublayer via an application independent $\alpha(\beta)$ interface. The incoming data from the $\alpha(\beta)$ interface is randomized, protected by FEC and multiplexed into the PMA frame. Protection includes interleaving.

The PMA frame is multiplexed from the PCS payload, and a header. The header consists of Indicator Bits (IB), special flags for the link activation and a syncword for PMA frame alignment.The PMA frame is output via the I interface towards the PMD sublayer.

The management block provides all OAM functions related to the PMA.

The PMA sublayer functional block diagram for both 10PASS-TS-O and 10PASS-TS-R is presented in Figure 62–2.

62.3.2 PMA Frame Format, Reference 1-2 section 7.2.3.1

Stet, with the exception that only Slow channel is applicable, i.e. F=0.

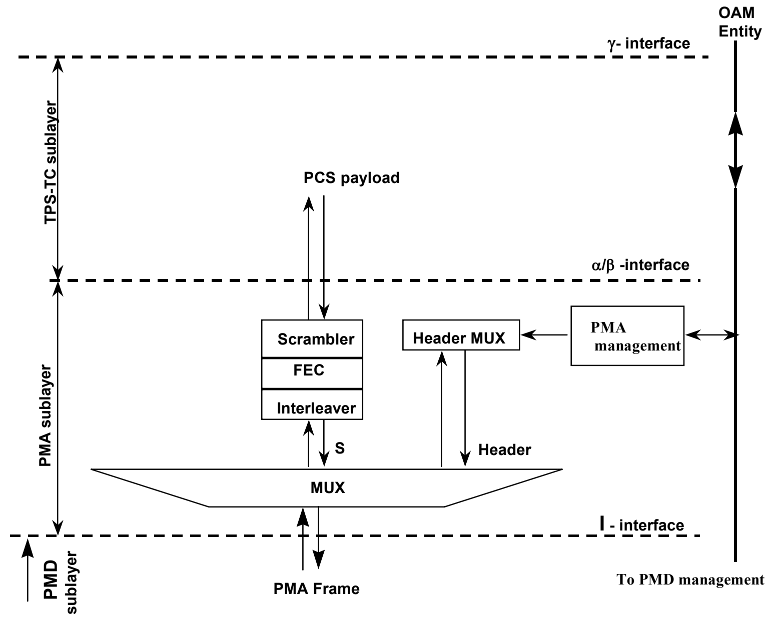

Figure 62–2—PMA Block Diagram

62.3.2.1 Sub-Frame Structure

The Sub-frames structure is identical to the Slow codeword defined in Reference 1-2 section 7.2.3.3, with the exception that only “single latency” is applicable.

62.3.2.1.1 Reference 1-2 section 7.3.1.1. Multiplexing of VOC and eoc

Stet.

62.3.2.1.2 Reference 1-2 section 7.3.1.2. Demultiplexing of VOC and eoc

Stet.

62.3.2.2 PMA Frame Header format

The PMA frame header includes a 2-octet syncword and a 3-octet control field. The syncword contains frame alignment information. The control field conveys management and auxiliary information. A 4-bit CRC is incorporated into the control fields for error detection at the receiving side.

In the Table 62–3, bit 7 of any octet is the MSB. Bit 7 of octet 0 is transmitted first.

62.3.2.2.1 Syncword Bytes

The syncword is intended for PMA frame delineation at both the 10PASS-TS-O and 10PASS-TS-R. It consists of two octets with fixed values: Sync 1 = 0xF6, Sync 2 = 0x28.

Table 62–3—Allocation of Frame Header Octets

Octet	Name	Description	Value
0	Sync 1	Syncword, octet 1	0xF6
1	Sync 2	Syncword, octet 2	0x28
2	Control 1	Control and management information, octet 1	
3	Control 2	Control and management information, octet 2	
4	Control 3	Control and management information, octet 3	

62.3.2.2.2 Control-1 Octet

The Control-1 octet contains the *o/r_trig* and *o/r_flag* bits, used for link activation support and the first five Indicator Bits (IB), intended for far end monitoring. The Control-1 octet is shown in Table 62–4. All IBs are coded 0 for normal operation, 1 for abnormal operation (defect or failure condition).

Table 62–4—Control-1 Octet Description

Bit	Name	Description	Value	Note
7	trig	o_trig signal in downstream direction r_trig signal in upstream direction	0 = Normal state, 1 = The active state	see section 62.5.6.3.4
6	flag	o_flag signal in downstream direction r_flag signal in upstream direction	0 = Normal state, 1 = The active state	
5	IB-1 (fp_1)	Far-end PCS defect or failure	0=Normal state 1=failure condition	See notes[a] below.
4	IB-2	reserved		
3	IB-3	reserved		
2	IB-4	reserved		
1	IB-5	reserved		
0	NTR	NTR is out of scope for this standard	1 = NTR marker is transmitted, 0 = Otherwise	

[a]Far-end PMA defect or failure indicators (fp) are used for PMA related primitives. Additional PMA failures can be indicated using spare bits of Control octets 1 and 2.

62.3.2.2.3 Control-2 Octet

Control-2 octet contains the first and second CRC bits and IB bits IB6:IB11. The Control-2 octet description is shown in Table 62-5. All IB shall coded 0 for normal operation, 1 for abnormal operation (defect or failure condition). CRC bits calculation is described in 62.3.2.2.5.

62.3.2.2.4 Control-3 Octet

Control-3 octet shall contain the third and the fourth *CRC* bits, two IB bits (IB-12:IB-13) and four bits for proprietary use. All IB bits are coded 0 for normal operation and 1 for abnormal operation (defect or failure condition). The control-3 octet description is shown in Table 62-6.

Table 62–5—Control 2 Octet Description

Bit	Name	Description	Value	Note
7	CRC_1	Frame header CRC check	First bit	
6	IB-6	Reserved	0 = Normal state 1 = abnormal state	PMD
5	IB-7 (los_cr1)	Far-end Loss of Carrier 1 energy	0 = normal state 1 = Loss state	see Reference 1-2 section 8.2.1.2
4	IB-8 (los_cr2)	Far-end Loss of Carrier 2 energy	0 = Normal state 1 = Loss state	
3	IB-9 (frdi)	Far-end Remote defect Indicator	0 = Normal state 1 = Loss state	PMA. see reference 1-1 section 10.3.1.4
2:1	IB-10: IB-11	Reserved	0 = Normal state 1 = abnormal state	
0	CRC_2	Frame header CRC check	Second bit	

Table 62–6—Control-3 Octet Description

Bit	Name	Description	Value	Note
7	CRC_3	Frame header CRC check	third bit	
6	IB-12 (FPO)	Far-end Power-off failure	0 = Normal state 1 = Power failure state	Power related primitive. see reference 1-1 section 10.3.3.2
5	IB-13 (flpr)	Far-end Loss-of-Power defect (dying gasp)	0 = Normal state 1 = Power failure state	
4:1	Reserved	For proprietary applications		
0	CRC_4	Frame header CRC check		Fourth bit

62.3.2.2.5 CRC-bits

The *CRC* bits *CRC_1* to *CRC_4* are computed as a remainder of multiplying the polynomial: $m_0D^{23} + m_1D^{22} + \ldots + m_{23}$ by D^4, and then dividing by $D^4 + D + 1$.

The polynomial coefficient m_0 is the MSB of the first Control 1 octet, m_{23} is the LSB of Control 3 octet and $m_8, m_{15}, m_{16}, m_{23}$ 0. *CRC_1* is the MSB of the remainder and *CRC_4* is the LSB of the remainder.

62.3.2.2.6 PMA Frame Delineation Algorithm

The PMA frame delineation algorithm is based on Sync_Events (syncword detection at the expected locations). The frame delineation state machine is presented in Reference 1-2 section 11.

Signal PMA_receive_synchronized is asserted when the state machine is in “SYNC” state.

62.3.2.2.7 Randomization and De-randomization

Randomization is performed in both transmission directions, by the same randomization algorithm prior to Reed Solomon (RS) encoding. Data de-randomization is performed after RS decoding. Randomization/de-randomization is performed on the PMA frame header, except the Sync1 and Sync2 octets, and on each of the sub-frames, except for RS redundancy octets.

The header and the sub-frames (except RS redundancy octets), that are transmitted in the same direction are randomized separately by the same randomization algorithm.

The randomizer/de-randomizer shall be self-synchronizing by the implementation.

The randomization algorithm in both 10PASS-TS-O and 10PASS-TS-R shall comply to the following:

$$D_{out}^{n} = D_{in}^{n} \oplus D_{out}^{n-18} \oplus D_{out}^{n-23}$$

The de-randomization algorithm shall reconstruct the randomized data. The block diagram of the randomizer is presented in Figure 62–3.

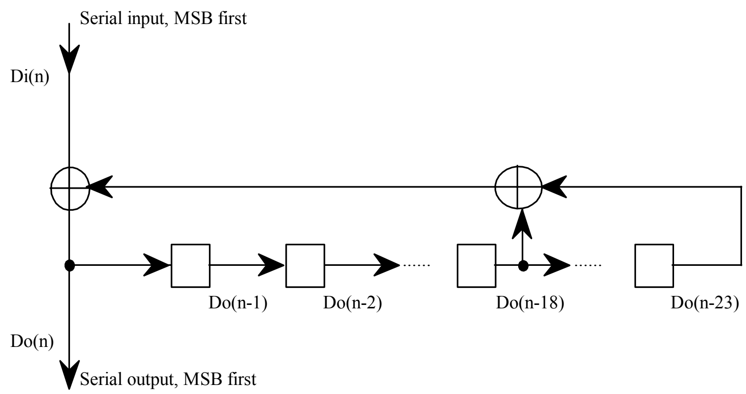

Figure 62–3—Randomizer

62.3.2.2.8 Forward Error Correction (FEC)

Reed-Solomon (RS) coding shall be used for Forward Error Correction (FEC). The applied code RS(N,K) is expressed by convention as two numbers, the first indicating the total codeword length (N), and the second indicating the number of data octets (K). The difference between these two numbers (N-K) is the number of FEC octets (redundancy octets). For this application, the codeword length (N) is always 200 and the number of data octets (K) is always 184.

The error correcting power of an RS code is related to the number of FEC octets (N-K). The number of corrected octets t per codeword equals to $t = \lfloor (N-K)/2 \rfloor$, where $\lfloor x \rfloor$ denotes truncation to the lower integer.

The downstream and upstream data protection shall use as generator polynomial:

$$g(x) = \prod_{i=0}^{N-K-1} (x + \mu^{i})$$

where μ is a root of the binary primitive polynomial: $x^8 + x^4 + x^3 + x^2 + 1$.

A data octet is identified within the Galois Field (256), with 256 elements as:,

$$(d_7 d_6 d_5 d_4 d_3 d_2 d_1 d_0) \Leftrightarrow \sum_{n=0}^{7} d_n \mu^n \Leftrightarrow \mu^p$$

(μ=02hex)

with a one-to-one mapping of octet values. (d_0 remains the LSB and d_7 remains the MSB. The MSB shall be transmitted first.)

An RS(N,K) codeword shall be defined as a function of the K data octets as:

$$[x^{N-K}(\sum_{i=0}^{K-1} \mu^{p(i)} x^i)] + [x^{N-K}(\sum_{i=0}^{K-1} \mu^{p(i)} x^i)] \;\; MOD\, g(x)$$

where the K most significant octets (coefficients of x^n , n=N-K..N-1) correspond to the K input data octets, and the N-K least significant octets (coefficients of x^n , n=0..N-K-1) correspond to the N-K output FEC octets.

The RS(N,K) encoding/decoding shall be implemented as a shortened RS(255,255-N+K) code. At the encoder side, 255-N octets, all set to 0, shall be appended before the K data octets at the input of the RS(255,255-N+K) encoder. These appended octets shall be discarded after the encoding procedure.

FEC machine should include the provision to introduce an intentional corruption into RS codeword for error monitoring verification purposes. The corruption shall be introduced upon the corresponding request from the management system into a single octet of the FEC redundancy field.

62.3.2.2.9 Interleaving

Each sub-frame of the PMA frame shall be interleaved before transmission by a convolutional interleaver, defined by the following parameters:

S - incoming sub-frame length, 200 octets;

I - interleaver block length, octets;

D - interleaving depth, octets;

M - interleaving depth index;

The interleaver shall function as follows:

The incoming codeword of 200 octets is divided into interleaver blocks of I octets long. The interleaver block length I, shall be equal to 25, 50, or 100. The octets within the interleaver blocks are numbered from *j* = 0 to *j* = *I-1*.

Each octet *j* of any interleaver block is delayed at the interleaver output by (D-1) ∗ *j* octets, where j = 0, 1, 2, … (I - 1) is the octet number within the interleaver block, *D* is the interleaving depth.

For example, the first octet of any block shall not be delayed, the third octet of any block will be delayed by 2 ∗ (D-1) octets and so on.

The value of (D-1) shall be a multiple of the interleaver block length *I*:

$D = M * I + 1$, where M is any integer.

The value M shall be programmable to any integer in the range of 0 to 64. The characteristics of the interleaver are summarized in Table 62–7. Setting M=0 cancels the interleaving

Table 62–7—Interleaver Characteristics

Parameter	Value	Notes
Block Length (I)	$I = 25, 50, or 100$ octets	$S = 200$ octets
Depth (D)	$D = M * I + 1$, octets	$M = 0, 1, 2, ..., 64$. Programmable
Erasure Correction (E)	$E = \lfloor t * I / S \rfloor * (M * I + 1)$, octets	$t = 8$ (RS error correction ability)
End-to-End Delay (DL)	$DL = M * I * (I - 1)$, octets	
Interleaver Memory Size	$MEM = M * I * (I - 1) / 2$, octets	

Notes:

a) The value D-1 characterizes the number of octets separating any two sequential octets of the same RS codeword. It is chosen in accordance with the required impulse noise protection.
b) The interleaver erasure correction E defines the maximum number of sequential corrupted octets in the data stream that can be corrected by the RS algorithm when interleaving is applied. Accordingly, the duration of noise pulses the system is protected from could be calculated as $E*8/R$, where R is the bit rate of the transmit signal over the line.
c) The range of values for M, listed in the above table, allows erasure correction up to 500 microseconds.
d) The symbol "$\lfloor....\rfloor$" indicates truncation to the lower integer.

Note: for clarification, an example of a convolutional interleaver is described below:

Interleaving is performed at the transmit side by writing the octets of the incoming Reed-Solomon codeword into a bank of *I* virtual shift registers numbered j = 0, 1, … (*I* - 1). The length of virtual shift register *j* in the interleaving memory is: $M*j$.

De-interleaving is performed at the received side by writing the octets of the incoming codeword into a bank of *I* virtual shift registers numbered j = 0, 1, … (*I* - 1). The length of virtual shift register *j* in the de-interleaving memory is: $M * (I-1-j)$.

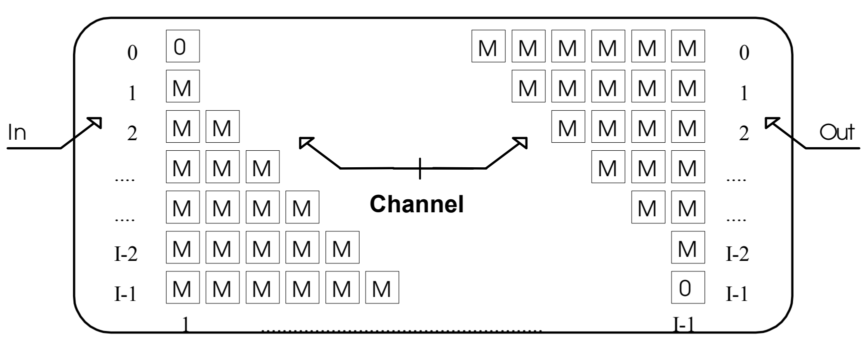

Figure 62–4—Interleaver Structure

The codeword is input either into the interleaving or de-interleaving memory by blocks of I octets at a time. The first octet from the codeword is written into the first shift register, the second octet into the second shift register and so on, up to the register (I-1). This process is repeated S/I times until the complete codeword is input into the bank of shift registers.

The codeword is output from the interleaving or de-interleaving memo*ry by reading blocks of I* octets at a time. The first octet from the codeword is read from the first shift register, the second octet from the second shift register and so on, up to the register (*I*-1). This process is repeated *S*/*I* times until the complete codeword is extracted from the bank of shift registers.

The structure of the interleaver is shown in Figure 62-4. The *I* parallel branches, numbered 0, 1.. (*I*-1) are implemented with a delay increment of *M*I* octets per branch. Each branch is a shift register with the length of 0**M*I*, *M*I*, 2*M*I*,.(*I*-1)**M*I* bytes. The de-interleaver is similar to the interleaver, but the branch indexes are reversed so that the largest interleaver delay corresponds to the smallest de-interleaver delay. De-interleaver synchronization is achieved by routing the first octet of an interleaved block of *I* bytes into the branch 0.

62.4 DMT PMD functional specifications

62.4.1 PMD Overview

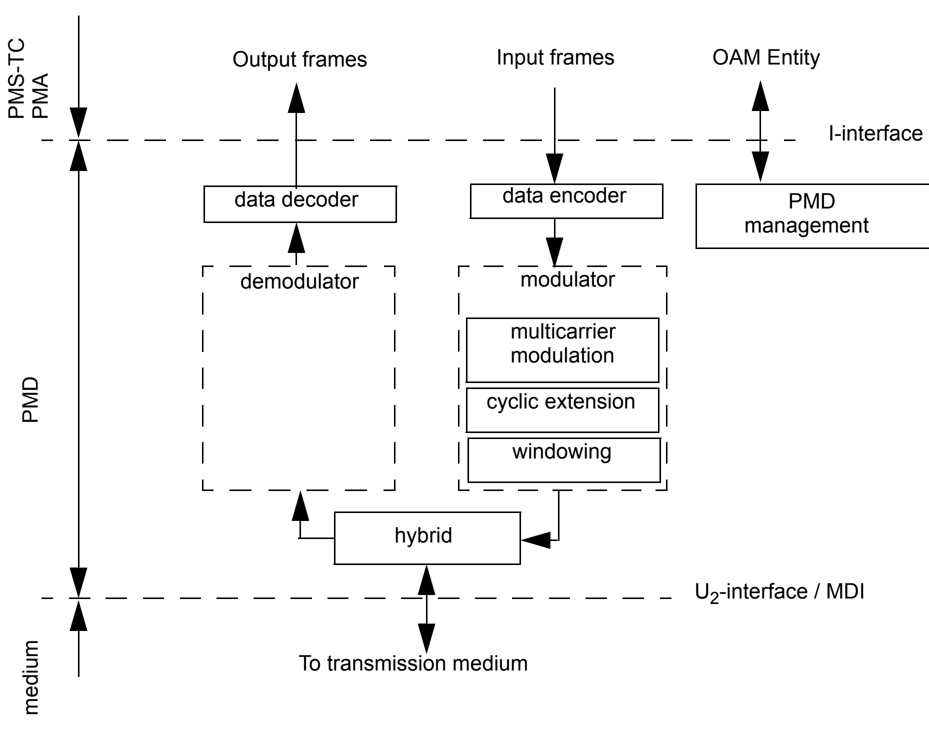

Figure 62–5—Functional diagram of PMD sublayer

The 10PASS-TS PMD functional model is presented in REFERENCE. In the transmit direction, the PMD layer receives frames from the PMA layer. It sends a DMT modulated signal towards the physical medium over the MDI.

The bytes within the frame are encoded to a set of QAM constellation points that are used to modulate the carriers of the DMT symbol. The time-domain symbol is cyclically extended and then windowed to reduce sidelobe energy.

In the receive direction, a modulated signal is received from the transmission medium over the MDI. The PMD layer outputs a data frame to the PMA layer. The receiver is responsible for equalization and demodulation of the signal.

62.4.2 PMD functional specifications

The 10PASS-TS PMD (and MDI) is specified by incorporating the MCM-VDSL standard, T1.424/Trial-Use Part 3, by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, T1.424/Trial-Use Part 3, will henceforth be referred to as MCM-VDSL.

62.4.3 General exceptions

The 10PASS-TS PMD is precisely the PMD specified as MCM-VDSL, with the following general modifications:

There are minor terminology differences between this standard and MCM-VDSL that do not cause ambiguity. The terminology used in 10PASS-TS was chosen to be consistent with other IEEE 802 standards, rather than with MCM-VDSL. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 62–8.

Table 62–8—Interpretation of general MCM-VDSL terms and concepts

MCM-VDSL term or concept	Interpretation for 10PASS-TS
PMS-TC	PMA
VTU-O, LT	10PASS-TS-O
VTU-R, NT	10PASS-TS-R
Transmission medium dependent interface	MDI
U1-interface (splitter present)	
U2-interface (splitter absent)	

62.4.4 Specific requirements and exceptions

The 10PASS-TS PMD (including MDI) shall comply to the requirements of MCM-VDSL Section 8 (Physical medium dependent (PMD) sublayer), Section 10 (Operations and maintenance), Section 11 (Link activation and deactivation), Section 12 (Normative Annex A - Handshake procedure for VDSL) and Section 14 (Informative Annex C - 8.625kHz tone spacing). Section 13 (Informative Annex B - FMT implementation) provides additional information useful to PMD sublayer implementers. Where there is conflict between specifications in MCM-VDSL and those in this standard, those of this standard shall prevail. Implementation of optional specifications in MCM-VDSL is not required for compliance with this standard. If optional features are implemented, their use is negotiated between 10PASS-TS-O and 10PASS-TS-R during initialization.

62.4.4.1 Reference sections 1 through 7

Clauses 1 through 7 of MCM-VDSL are not applicable

62.4.4.2 Reference section 8

62.4.4.2.1 Reference section 8.1

Stet.

62.4.4.2.2 Reference section 8.2

8.2.1 of MCM-VDSL is replaced with the following:

10PASS-TS transceivers shall use Frequency Division Duplexing (FDD) to separate upstream and downstream transmission. 10PASS-TS transceivers shall support modulation of a minimum of $N_{SC,min}$ = TBD subcarriers. The modulation shall use a maximum number of sub-carriers equal to $N_{SC,max} = 2^{n+8}$, where n can take the values 0, 1, 2, 3, 4.[1] Disjoint subsets of the N_{SC} sub-carriers shall be defined for use in the downstream and upstream directions. These subsets are determined by the choice of frequency plan. The exact subsets of sub-carriers used to modulate data in each direction shall be determined during initialization and shall be based on management system settings and the signal-to-noise ratios (SNRs) of the subchannels. In many cases the number of sub-carriers used in a direction will be less than the maximum number allowed by the partitioning.

The frequency plans shall consist of two upstream bands denoted as 1U and 2U and two downstream bands denoted as 1D, 2D. The bands shall be allocated as shown in Figure 62–6. The values of the splitting frequencies f_i shall be as given in Annex 62A. Adherence to a particular frequency plan may be mandatory under local regulations when 10PASS-TS is deployed in public networks. Support for other frequency plans, for use in private networks, is optional.

The use of the band between 25 kHz and 138 kHz shall be negotiated during the initialization to indicate if the capability exists and select one of the following options:

a) Use of the band for upstream transmission
b) Use of the band for downstream transmission
c) The band is not used.

The use of the spectrum above 12 MHz is outside the scope of this standard.

The cyclic extension length is specified by the value of parameter *m*. In 10PASSTS, the value *m*=20 is mandatory. Support for other values is out of scope.

8.2.3.1 of MCM-VDSL is further clarified by the following text:

Support for pilot tones is mandatory. 10PASS-TS-R PHYs shall support the transmission of a pilot tone on any downstream tone.

8.2.3.4 of MCM-VDSL is replaced with the following:

The use of synchronous mode as defined in MCM-VDSL 8.2.3.4 may improve operation in certain binder environments and is a system implementation item which is outside the scope of this standard.

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[1]Editor's Note: Certain values of n may be removed after fixing the minimum value of N_{SC}.

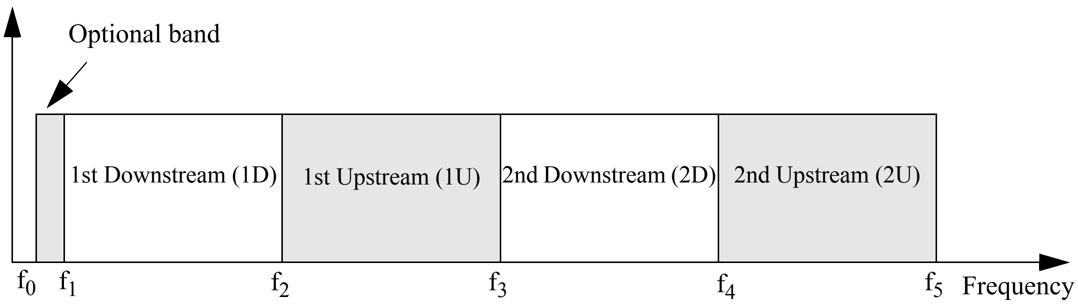


Figure 62–6—10PASS-TS band allocation

8.2.4 of MCM-VDSL is replaced with the following:

To mitigate the effects of FEXT from short lines into long lines in distributed cable topologies, upstream power back-off shall be applied. Transceivers shall be capable of performing frequency-dependent power back-off.

Only one UPBO mode shall be supported as described below:

a) It shall be possible for the network management system to set the limiting transmit PSD template PSD0 for the 10PASS-TS-R to one of the standard transmit PSD templates (Template M1, Template M2) as defined in the applicable section of 62A.3.4.
b) The 10PASS-TS-R shall perform UPBO autonomously, i.e., without sending any significant information to the 10PASS-TS-O until the UPBO is applied.
c) After UPBO has been applied as described in b), the 10PASS-TS-O shall be capable of adjusting the transmit PSD selected by the 10PASS-TS-R; the adjusted transmit PSD shall be subject to the limitations given in the applicable section of 62A.3.4.

To enable the 10PASS-TS-R to initiate a connection with the 10PASS-TS-O, which will occur before UPBO has been applied, the 10PASS-TS-R shall be allowed to cause more degradation to other loops than expected when using the mode described below.

NOTE - Initiation refers to a request from the 10PASS-TS-R to start the initialization of the link. The particular method is in MCM-VDSL 11.2.

The 10PASS-TS-R shall explicitly estimate the electrical length of its line, kl_0, and use this value to calculate the transmit PSD template $TxPSD(kl_0,f)$. The 10PASS-TS-R shall then adapt its transmit signal PSD to conform to the template $TxPSD(kl_0,f)$ and the corresponding PSD mask which is defined in the applicable section of 62A.3.4.

The transmit PSD template shall be calculated as:

$$TxPSD(kl_0,f) = \min\left(PSD\_REF(f) + LOSS(kl_0,f),\ PSD_0\right),\ \text{in dBm/Hz} \qquad (1)$$

where PSD_0 as defined in a) above, and:

$$LOSS = kl_0\,\mathrm{sqrt}(f),\ \text{in dB} \qquad (2)$$

where the *LOSS* function is an approximation of the loop attenuation (insertion loss).

NOTE - The estimation of the electrical length should be sufficiently accurate to avoid spectrum management problems and additional performance loss.

PSD_REF will depend on the limiting transmit PSD template PSD_0 and on the noise model that is relevant for a given deployment scenario. The values of *PSD_REF* shall be as given in Table 62–9. The same bandwidth as for all regular transmit PSD masks defined in the applicable section of 62A.3.4 shall be used to check the conformance of *TxPSD* with power back-off. The general methodology for testing PSD conformance is defined in 6.1 of T1.417. Conformance with the PSD template shall be verified using a 100 kHz sliding window in the in-band frequency range below 1 MHz and a 1 MHz slowing window in the in-band frequency range above 1 MHz..

Table 62–9—Reference PSDs (f is in MHz, the PSD level is in dBm/Hz)

	Noise A environment		Noise F environment	
	Template M1	**Template M2**	**Template M1**	**Template M2**
Band 1U	$-60 - 22.00 \times \sqrt{f}$	$-53 - 24.47 \times \sqrt{f}$	$-60 - 18.54 \times \sqrt{f}$	$-53 - 21.19 \times \sqrt{f}$
Band 2U	$-60 - 17.18 \times \sqrt{f}$	$-54 - 18.93 \times \sqrt{f}$	$-60 - 16.865 \times \sqrt{f}$	$-54 - 18.69 \times \sqrt{f}$

NOTE 1 - Bands 1U and 2U are as given in Figure 62–6.

Subclause editor's note: Is there any reason to assume that changing the allocation of band 1U and band 2U would necessitate a change to the above formulas?

NOTE 2 - Noise A and F environments correspond to specific deployment scenarios that are defined in T1.424/Trial-Use 12.2

PSD_REF shall be input via the management interface and shall be transmitted from the 10PASS-TS-O to the 10PASS-TS-R (see MCM-VDSL 11.2.4.2.1.1).

The 10PASS-TS-R shall estimate the insertion losses of the upstream bands based on the received downstream signals. From this, the shape of the *LOSS* function (or, equivalently, the electrical length) as defined above shall be derived. The 10PASS-TS-R shall then compute the transmit PSD by dividing the reference PSD in the upstream bands by the estimated *LOSS* function. Next, the 10PASS-TS-R shall take a tone-by-tone minimum of this computed PSD and the maximum allowed transmit PSD in the upstream direction. The result shall be used as the initial upstream transmit PSD. The PSD received by the 10PASS-TS-O should approximate the reference PSD. Upon receiving signals from the 10PASS-TS-R, the 10PASS-TS-O shall compare the actual received PSD to the reference PSD. If necessary, it shall instruct the 10PASS-TS-R to fine-tune its PSD.

The 10PASS-TS-O shall also have the capability to directly impose a maximum allowed transmit PSD at the 10PASS-TS-R. This maximum transmit PSD shall also be input via the management interface and shall be transmitted from 10PASS-TS-O to 10PASS-TS-R in the early stages of the initialization. The 10PASS-TS-O shall allow the operator to select one of these two methods. If the PBO is defined as a maximum transmit PSD at the 10PASS-TS-R, the 10PASS-TS-R shall adjust its transmit PSD such that it does not exceed the maximum allowed transmit PSD. The restrictions specified in the previous paragraph shall also apply in this case (i.e. the 10PASS-TS-O shall not impose a transmit PSD mask that violates the mask specified there).

8.2.5 of MCM-VDSL --- Editor's Note: The range of Bmax_d and BMax_u defined in MCM-VDSL 8.2.5 may be restricted by this document. The appropriate values are for further study.

8.2.8 is replaced with the requirements specified in 62A.3.4.

All other subclauses in MCM-VDSL Clause 8 are referenced *stet*.

62.4.4.3 Reference section 9

Clause 9 of MCM-VDSL is not applicable to the PMD of 10PASS-TS.

62.4.4.4 Reference section 10

62.4.4.4.1 Reference section 10.1

10.1 of MCM-VDSL is replaced with the relevant specifications in Clause 55 and Clause 61.

Subclause editor's note: *Precise reference to be added.*

62.4.4.4.2 Reference section 10.2

10.2 of MCM-VDSL is replaced with the relevant specifications in Clause 55 and Clause 61.

Subclause editor's note*: Precise reference to be added.*

62.4.4.4.3 Reference section 10.3

10.3 of MCM-VDSL is replaced with the relevant specifications in Clause 55 and Clause 61.

Subclause editor's note*: Precise reference to be added.*

62.4.4.4.4 Reference section 10.4

10.4 of MCM-VDSL is replaced with the relevant specifications in Clause 55 and Clause 61.

Subclause editor's note: *Precise reference to be added.*

62.4.4.4.5 Reference section 10.5

10.5 of MCM-VDSL is replaced with the relevant specifications in Clause 55 and Clause 61.

Subclause editor's note: *Precise reference to be added.*

62.4.4.4.6 Reference section 10.6

10.6 of MCM-VDSL is replaced with the relevant specifications in Clause 55 and Clause 61.

Subclause editor's note*: Precise reference to be added.*

62.4.4.4.7 Reference section 10.7

Stet.

62.4.4.5 Reference section 11

62.4.4.5.1 Reference section 11.1

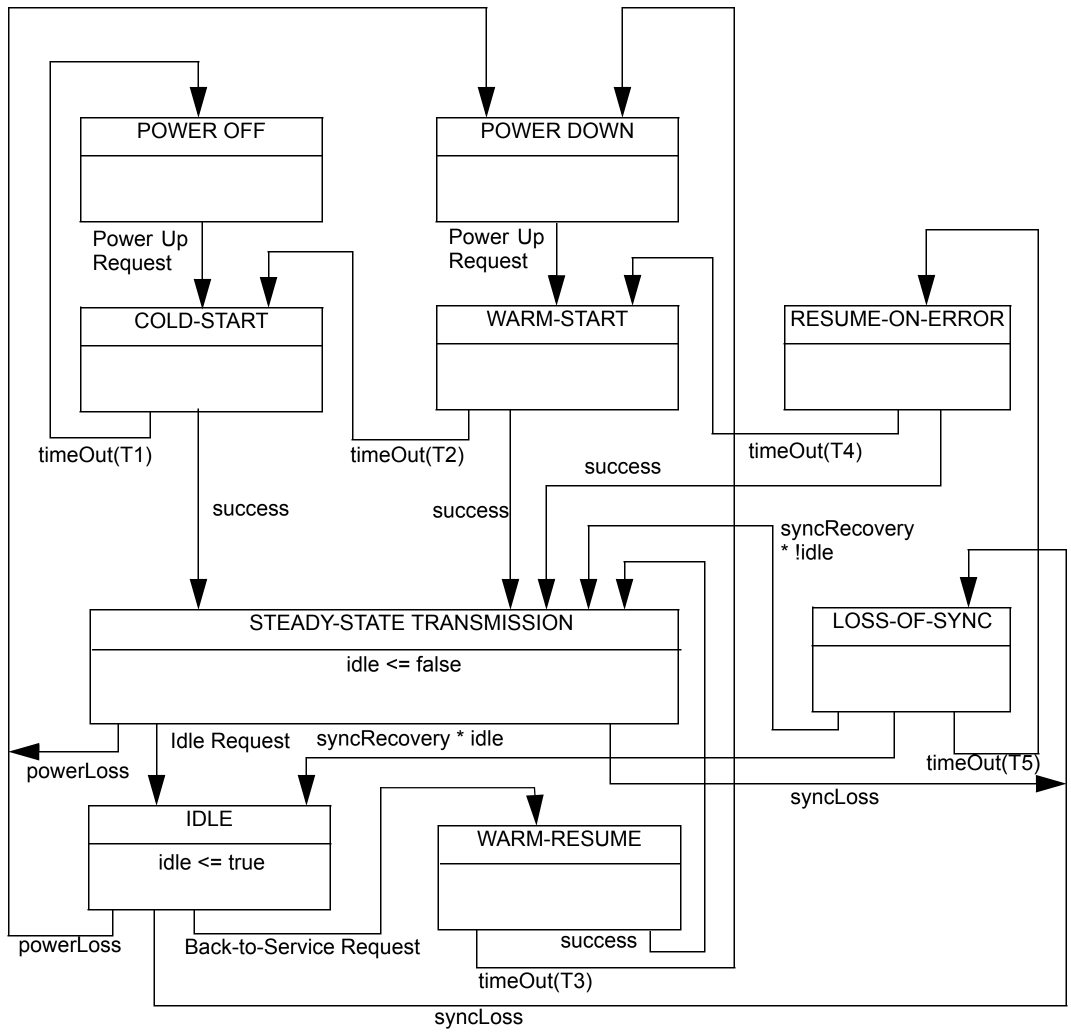


Figure 62–7—Link state and timing diagram

62.4.4.5.2 Reference section 11.2

Stet.

62.4.4.6 Reference section 12 (Annex A)

Clause 12 of MCM-VDSL is replaced with the following: The 10BASE-TS handshake procedure is based on ITU-T Recommendation G.994.1 (G.hs). It shall use the 4.3125kHz signalling family and the duplex transmission mode. The handshake shall proceed as specified in 61.3.

Editor's Note: The codewords for use with 10PASS-TS are specified in 61.3. When agreement is reached on the set of optional and mandatory settings and features for 10PASS-TS (DMT), the appropriate changes will be made to 61.3.

62.4.4.7 Reference section 13 (Annex B)

Stet.

62.4.4.8 Reference section 14 (Annex C)

Stet. 10PASS-TS PHYs shall support operation as described in Reference Annex C.

62.4.5 Transmission medium interface characteristics

This subclause specifies the interface between the transceiver and the transmission medium (U2 reference point). The interface at U1 reference point (Editor's note: reference to VDSL reference model to be added here) is specified by the corresponding characteristics of the service splitter. The definition of the service splitter is outside the scope of this standard. Relevant specifications may be found in T1.424/Trial-Use Clause 18 and Clause 19.

62.4.5.1 Transmit signal characteristics

62.4.5.1.1 Wide-band power

The average wide-band power of the transmitted 10PASS-TS signal measured over the frequency range between 25 kHz to 12 MHz shall be no greater than the values listed in Table 62–10 when terminated with resistive impedance of R_V = 100 Ohm.

Table 62–10—10PASS-TS maximum transmit power

Central office deployment scenario		Cabinet deployment scenario	
Downstream [dBm]	**Upstream [dBm]**	**Downstream [dBm]**	**Upstream [dBm]**
14.5	**14.5**	**11.5**	**14.5**

NOTE 1 - For compliance with this requirement, the 10PASS-TS transceiver shall be terminated with the impedance R_V and be configured to transmit pseudo-random data with any repetitive framing patterns enabled.

NOTE 2 - Power shall be measured across the termination resistance of R_V. No energy shall be inserted into the POTS/ISDN port of the splitter (if applied) during this test.

62.4.5.1.2 Power spectral density (PSD)

Transmit PSD is characterized by the PSD template and PSD mask. PSD templates and masks are defined in Annex 62A.

62.4.5.1.3 Egress control

To avoid potential harm to amateur radio service due to radiated emission from 10PASS-TS, it shall be possible to reduce the PSD of the transmit signal within the amateur radio bands. Specifications for egress power control are described in Annex 62A.

62.4.5.2 Termination impedance

A termination impedance of R_V = 100 Ohm (purely resistive, either source or load) shall be used over the entire 10PASS-TS frequency band for both the 10PASS-TS-O and 10PASS-TS-R when matching to the metallic wire-pair.

This termination impedance approximates (and is based upon) the insertion-point impedance of the VDSL test loop. It enables a compromise high-frequency impedance match to the various types of unshielded cable in metallic access networks.

62.4.5.3 Return loss

The return loss requirement is defined to limit signal power uncertainties due to the tolerance of the line interface impedance. The return loss *RL* specifies the amount of reflected differential signal upon a reference impedance R_V

$$RL = 20 \times \log\left|\frac{Z + R_V}{Z - R_V}\right| \tag{3}$$

where Z is the internal impedance of the VTU. Note that in equation (3), the log is taken to base 10, such that *RL* is expressed in dB

The in-band return loss value of the 10PASS-TS transceiver shall be greater than or equal to 12 dB. The out-of-band return loss value shall be greater than or equal or 3 dB. In-band and out-of-band frequencies are defined by the frequency plan as shown in Figure 62–6 and by the transmit direction.

The value of 12 dB assumes a flat transmit PSD is applied over the entire in-band region. Requirements may be relaxed in the frequency ranges of reduced PSD values. The exact value requirements are for further study.

The return loss shall be measured on a resistive test load of R_V = 100 Ohm while the tested implementation of the 10PASS-TS transceiver is powered.

NOTE - If a splitter is used, the return-loss requirements shall be met for the full range of possible values of the POTS/ISDN port termination.

62.4.5.4 Output signal balance

Output signal balance (*OSB*) is a measure of unwanted longitudinal signals at the output of the transceiver. The longitudinal output voltage (V_{cm}) to the differential output voltage (V_{diff}) ratio shall be measured while the VTU transmitter is active in accordance with ITU-T Recommendation G.117 and ITU-T Recommendation O.9.

$$OSB = 20\log\left|\frac{V_{diff}}{V_{cm}}\right| \tag{4}$$

The *OSB* of the 10PASS-TS transceiver shall be equal to or greater than 35 dB in the entire 10PASS-TS band.

NOTE - The equipment balance should be better than the anticipated cable balance in order to minimize the unwanted emissions and susceptibility to external RFI. The typical worst case balance for an aerial drop-wire has been observed to be in the range 30 - 35 dB, therefore the balance of the 10PASS-TS equipment should be equal or better.

62.5 SCM PMD functional specifications

62.5.1 Scope

The presented SCM PMD functionality is specified by incorporating of the following references:

- Reference 1-1: T1.424/Trial-Use standard Part 1
- Reference 1-2: T1.424/Trial-Use standard Part 2
- Reference 2: ITU-T G.993.1
- Reference 3-1: ETSI TS 101 270-1
- Reference 3-2: ETSI TS 101 270-2.

62.5.1.1 PMD functional model

The PMD sublayer functional model is presented in Figure 62–8. In the transmit direction the input frame (see 62.3.2) comes from the PMA via I-interface. The frame is split into one or two streams (Figure 62–8 shows splitting into two streams). Each stream is encoded, modulated and sent onto the transmission medium via U_2-interface (see 62.5.4). In the receive direction the carriers received in both bands are demodulated, decoded and multiplexed into the output frame, which has the same structure as the input frame. The output frame is sent to the PMA via the I-interface.

Each stream is transmitted in a separate frequency band (see 62.5.1.2). The band-pass filter restricts the transmit out-of-band power to prevent crosstalk. The diplexer provides additional decoupling between transmit and receive signals. The signal transmitted in a particular band is called a carrier. One or two carriers can be transmitted in each transmission direction, although if one carrier can transmit all the input data, the other carriers may not be used. In this case both the splitter and multiplexer are bypassed.

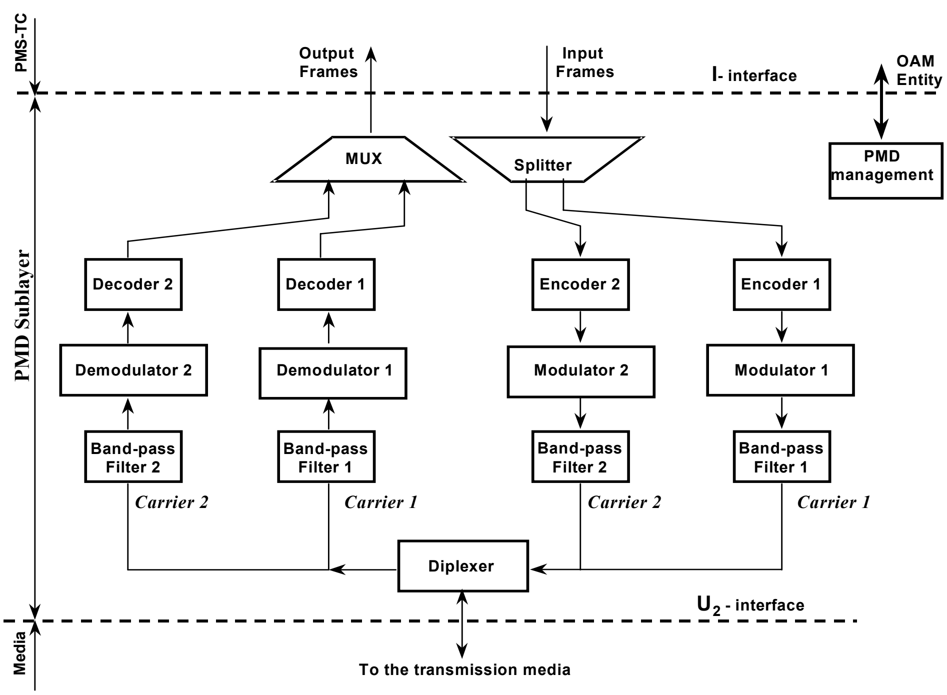


Figure 62–8—PMD sublayer functional model

62.5.1.2 Duplexing method

The transceiver shall use Frequency Division Duplexing (FDD). Each of the carriers shall be transmitted in separate frequency bands. The band separating frequencies are regionally specific. The currently standardized values are specified in Reference 1-1 section 7.5, in Reference 2 section 6.1 and Annexes A, B, C, and in Reference 3-1 section 8.1.5. Other band plans are described in clause 62A.

62.5.1.3 Reference 1-2 section 6.1.3. Timing

Stet.

62.5.2 Transmit functionality

62.5.2.1 Splitting, Reference 1-2 section 6.2.1

Stet.

62.5.2.2 Coding and modulation, Reference 1-2 section 6.2.2

Stet, with the exception that only Base-Band Spectral shaping (BSS) is used.

62.5.2.2.1 Modified Reference 1-2 section 6.2.2.1. Constellation encoder

Stet.

Additionally to specified in the Reference, the 2-point, 512-point, and 1024-point constellations are supported. The differential encoding for 2-point constellation shall be as specified in Table 62–11. The constellation diagram for 512-point is given in Figure 62–9.

Table 62–11—Differential encoding for 2-point constellation

	Previous quadrant	Sign of previous symbol	Current quadrant	Sign of current symbol
bit value (b_1)	#	I_{n-1} Q_{n-1}	#	I_{n-1} Q_{n-1}
0	1st	1 1	1st	1 1
1	1st	1 1	3rd	-1 -1
0	3rd	-1 -1	3rd	-1 -1
1	3rd	-1 -1	1st	1 1

For the first quadrant of 1024-point constellation the values of I_n and Q_n expressed in 2-s complement are presented in Table 62–12, where b_3, .. b_{10} are third to tenth bits of the coded 10-bit symbol.

NOTE: The following example clarifies usage of Table 3: for $b_3b_4b_5b_6b_7b_8b_9b_{10}$ =00000001, we get: x1-x4=0, y1-y3=0, y4=1, and I_n = 00001(b)= 1(d), and Q_n= 00011(b)= 3(d). Respectively, constellation point with I_n =1, Q_n= 3 will be coded 00000001.

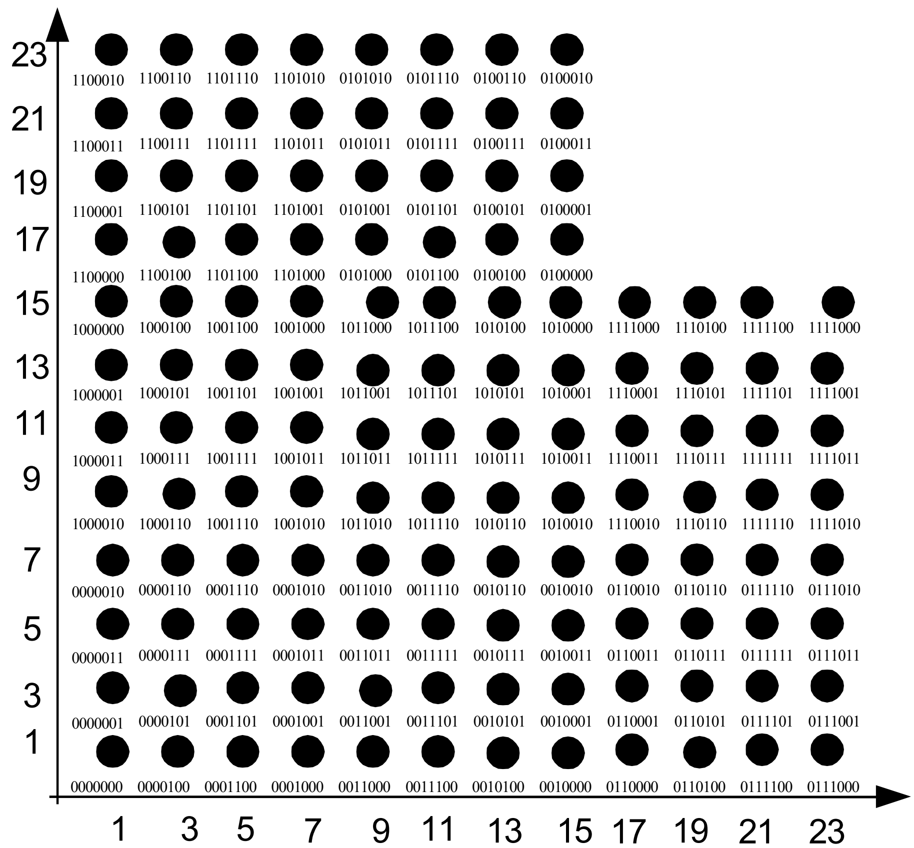


Figure 62–9—512-point constellation and bit mapping (first quadrant)

Table 62–12—Encoding for 1024-point constellation (first quadrant)

X-digits	Y-digits
$x1=b_3$	$y1=b_7$
$x2=x1+b_4$	$y2=y1+b_8$
$x3=x2+b_5$	$y3=y2+b_9$
$x4=x3+b_6$	$y4=y3+b_{10}$
I_n = x1 x2 x3 x4 1	
Q_n= y1 y2 y3 y4 1	

NOTE - The second, third and fourth quadrant mappings shall be derived from the mappings in the first quadrant presented in Figure 62–9 and Table 62–12 by rotating the quadrant counter-clockwise by 90 degrees, 180 degrees, and 270 degrees, respectively.

62.5.2.2.2 Modified Reference 1-2 section 6.2.2.2. Modulator

Stet.

Additionally to specified in the Reference, the amplitudes of the In and Qn components shall maintain the relative values of 17, 19, … 31 as depicted in the constellation diagram in Figure 62–9 and Table 62–12, with a tolerance of ±0.06 relative to these values.

62.5.2.2.3 Modified Reference 1-2 section 6.2.2.2.1. Symbol rates and carrier frequencies

All available symbol rates (*SR*) in both downstream and upstream directions shall be multiples of the Basic Symbol Rate (*BSR*):

$SR = s \times BSR$,

where s is an integer, BSR = 16.875 kbaud.

The carrier signal frequencies f_c shall be a rational multiple of *BSR*:

$f_c = k \times BSR$, [MHz],

where k is an integer. The resulting f_c shifting granularity is equal to 16.875 kHz.

NOTE: The value SR/f_c shall be an exact ratio of two integers under all possible frequency tolerances.

62.5.2.2.4 Modified Reference 1-2 section 6.2.2.2.2. Spectral shaping filters

The low-pass filters of both in-phase and quadrature paths (Figure 62–8) shall exhibit spectral magnitude function |G(f)| approximating a square-root raised-cosine spectrum with an excess bandwidth parameter of α:

$$|G(f)| \approx g_0 \begin{Bmatrix} 1 & , \ |f| \le f_1 \\ \cos\left(\frac{\pi T}{2\alpha}\left[|f| - f_1\right]\right) & , \ f_1 \le |f| \le f_2 \\ 0 & , \ \text{elsewhere} \end{Bmatrix}, \ f_1 = \frac{1-\alpha}{2T}, \ f_2 = \frac{1+\alpha}{2T}$$

The transceiver must provide the excess bandwidth parameter of 0.2. Other excess bandwidth parameters, in the range between 0.1 to 0.2 with granularity of 0.025 are supported.

As a result of shaping, the transmit signal of any carrier using α = 0.2 shall meet the power spectrum *G* template and the group delay *D* template as defined in Table 62–13. The lower and upper limits of the attenuation are defined as a function of the normalized frequency

: (5)

$$x = \frac{f - f_c}{SR/2}$$

.

Table 62–13—Carrier in-band power spectrum and group delay distortion templates

Normalized frequency, x	*G* nominal dB	*G* min dB	*G* max dB	*D(x)-Dmin*
-1.5	inf	N/A	< -40	N/A
-1.4	inf		< -40	
-1.3	inf		< -30	
-1.2	inf		< -20	
-1.15	-14.2	-19	-10	< 8T
-1.1	-8.4	-12	-6.0	< 5T
-1.05	-5.1	-8.5	-3.0	< 4.5T
-1.0	-3.0	-4.0	-2.0	< 4T
-0.95	-1.6	-2.6	-0.6	< 3T
-0.9	-0.7	-1.7	+0.3	
-0.8	0	-1.0	+1.0	
0	0	-1.0	+1.0	
0.8	0	-1.0	+1.0	
0.9	-0.7	-1.7	+0.3	
0.95	-1.6	-2.6	-0.6	
1.0	-3.0	-4.0	-2.0	< 4T
1.05	-5.1	-8.5	-3.0	< 4.5T
1.1	-8.4	-12	-6.0	< 5T
1.15	-14.2	-19	-10	< 8T
1.2	inf	N/A	< -20	N/A
1.3	inf		< -30	
1.4	inf		< -40	
1.5	inf		< -40	

NOTES

1. The absolute value of nominal transmit PSD [dBm/Hz] corresponds to the template level of 0 dB.

2. The in-band part of the templates for *G* and *D* defined by $|x| \le 1.2$ ($a = 0.2$) accounts for all the effects of the band-pass filter (Figure 62–8) on spectral shaping.

3. The values of *Gmax* defined by $|x| > 1.2$ may be not sufficient to meet generic requirements for out-of band VDSL PSD specified in subclause 62.5.4.2. The band-pass filter should provide the additional out-of-band filtering, if necessary.

4. The templates relate only to flat-shaped and unnotched transmit PSD. For non-flat transmit PSD the templates are for further study.

5. *Dmin* is the minimum group delay within the in-band part of the spectrum:

Dmin = min *D(x)* for $|x| \le 1.2$

62.5.2.2.5 Bit rates

The total bit rate (*TR*) in the given transmission directions is determined by symbol rates *SR1*, *SR2* and constellation sizes *C1*, *C2* of both carriers:

$$TR = SR_1 \times \log_2 C_1 + SR_2 \times \log_2 C_2, \qquad (6)$$

where index 1 or 2 corresponds with carrier-1 and carrier-2, respectively.

NOTE: The minimum available transmission bit rate granularity depends on the symbol rate granularity *BSR* = 16.875 kHz. For the used constellation size of 2-10 bits, the total bit rate granularity for different cases varies from 33.75 kb/s to 168.75 kb/s.

62.5.2.2.6 Reference 1-2 section 6.5.1.3. Spectral allocation of the Transmit Signal

Stet.

62.5.3 Reference 1-2 section 6.3. Receive Functionality

Stet.

62.5.4 Physical characteristics of the transmitter

Physical characteristics of the transmitter are specified at the MDI, Figure 62–8. The MDI-O and MDI-R reference points define interfaces between the PMD and the physical media at the 10PASS-TS-O and 10PASS-TS-R, respectively. Both interfaces are identical and described in Reference 1-1 section 5.

62.5.4.1 Transmit PSD and wideband power control

All options to control transmit PSD and wideband power are available independently in both transmission directions. Control parameters are defined in Clause 30. Access to PSD control through MDIO is defined in Clause 45. Access to remote PSD parameters during handshaking at link startup is defined in 61.3.

62.5.4.1.1 PSD setup

The PSD of the transmit signals in both directions shall comply with the set PSD templates and the wideband power limitation to comply with regionally specific PSD templates and wideband power limitations. The standardized values are specified in Annex 62A.

62.5.4.1.2 PSD adjustment

The system shall be capable to adjust the value and shape transmit PSD. The adjustment is provided via the management system, as specified in Clause 30. Access to the parameters via the MDIO interface is defined in Clause 45. Additional information is available in Annex 62A and subclause 62.5.6.2.2. In particular, the system shall provide capability for PSD reduction in the frequency range below 1.1 MHz to provide spectral compatibility with CO-based ADSL for cabinet and MDU deployments.

62.5.4.1.3 Reference 1-2 section 6.4.2.1.2. Egress control

Stet.

62.5.4.1.4 Modified Reference 1-2 section 6.4.2.1.3. Upstream power back-off

Stet.

62.5.4.1.4.1 Modified Reference 1-2 section 6.4.2.1.3.1. Start-up power back-off

Stet,

except the values of Reference PSD (*PSD_REF*), electrical length (kl_o) of the loop, and *LOSS_CORR* are regionally specific. The standardized values are specified in Reference 1-1 section 7.1.3.1.1, Reference 1-2 section 6.4.2.1.3.1, Reference 3-1 section 8.2.7.1, and Reference 3-1 section 5.2.4.2.3.3. Refer to Annex 62A for profile definitions including regional variance of power back-off characteristics.

NOTE: If bridged taps is not a concern for the particular region, it is recommended to set *LOSS_CORR* = 0.

62.5.4.1.4.2 Reference 1-2 section 6.4.2.1.3.2. Steady-state PSD shaping

Stet.

62.5.4.2 Out-of-band PSD mask

The out-of-band PSD mask is defined in Figure 62–10.

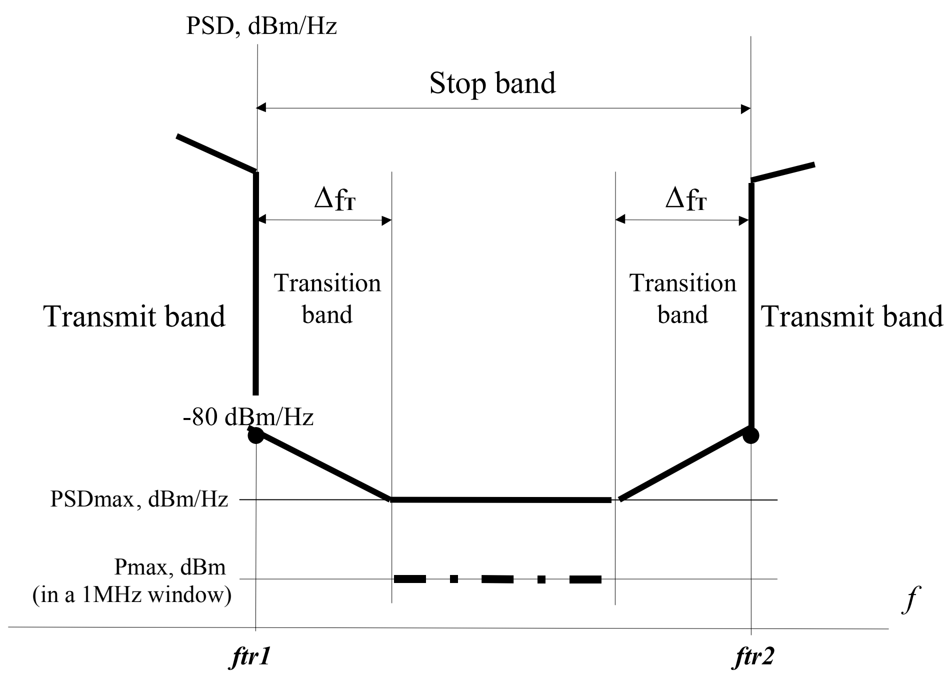


Figure 62–10—Out-of-band PSD mask

Two transmit bands are shown, with the stop band in between them, and can be either the two upstream or two downstream bands. Band separating frequencies *ftr1* and *ftr2* can get any values specified in section 62A. Transition bands $\Delta \mathbf{f_T}$ reflect the transmit signal roll-off occupying a part of the adjacent receive band. The value of transition bands $\Delta \mathbf{f_T}$ for all bands characterized by *ftr* > 1MHz should be less than 175 kHz. For bands with *ftr* ≤ 1MHz the value Δf_T is for further study.

Within the transition bands (i.e. from *ftr1* to (*ftr1* + Δf_T) and from *ftr2* to (*ftr2* – Δf_T)), the transmit PSD mask either decreases linearly (on a linear scale) from –80 dBm/Hz to a value of PSDmax. The transmit PSD and the total transmit power measured in a 1 MHz sliding window shall be limited by numbers presented in Table 62–14. Table 62–14 defines the corners of a straight-line graph of the out-of-band PSD mask versus frequency on a linear-to-linear scale.

Table 62–14—Out-of-band PSD mask

Frequency MHz	Maximum PSD *PSDmax*, dBm/Hz	Maximum Power in a 1MHz sliding window *Pmax*, dBm	Frequency MHz	Maximum PSD *PSDmax*, dBm/Hz
< 0.12	-120	-	< 0.12	-120
0.12 - 0.225	-110	-	0.12 - 0.225	-110
0.225-4.0	-100	-	0.225-4.0	-100
4.0 – 5.0	-100	-50	4.0 – 5.0	-100
5.0 - 30.0	-100	-52	5.0 - 30.0	-100

NOTE: The power in a 1 MHz sliding window is measured in a 1MHz bandwidth starting at frequency *ftr1* + Δf_T of the corresponding transmit signal band and finishing at the next transition frequency *ftr2* - Δf_T, as defined in Figure 62–10. If the value of the stop band minus $2\Delta f_T$ is narrower than 1 MHz, the bandwidth of the measurement device should be set to ω, with ω less than the value of the stop band minus $2\Delta f_T$, and the measured result should be recalculated to the 1 MHz sliding window as: $Pmax = P - 10\log(\omega)$, where *P* is the measured result in dBm, ω is the bandwidth used for the measurement in MHz.

62.5.4.3 Return loss

The return loss shall be estimated as:

$$RL, dB = 20\log\left|\frac{Z + R_V}{Z - R_V}\right|$$

where *Z* is the internal impedance of the transceiver, and R_V is the resistive test load. The return loss shall be measured while the tested implementation of the transceiver is powered. The value of *Rv*is regionally specific. It shall be 100Ω±0.2% for North America applications and 135Ω±0.2% for European applications.

The return loss mask for any carrier, in transmit or receive direction, shall be as shown in Figure 62–11.

62.5.4.4 Reference 1-1 section 7.4. Output signal balance

Stet.

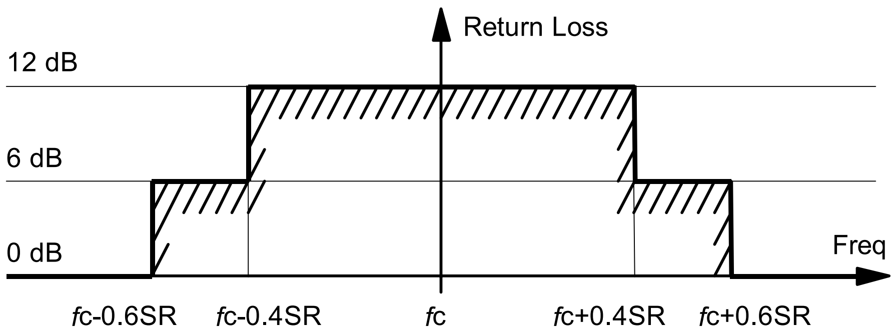


Figure 62–11—Return loss mask

62.5.5 Overhead Control Channel (OCC)

The OCC is defined to support link activation, and provide link maintenance, performance monitoring, and modification of transmission parameters. Communication over OCC is always initiated by the EFM-O; the EFM-R replies to the EFM-O upon successful reception of a message.

In the following referenced sections the OCC is referred as VDSL Overhead Control (VOC) channel.

62.5.5.1 Reference 1-2 section 8.1.1. VOC messages

Stet.

62.5.5.2 Reference 1-2 section 8.1.2. VOC message transport

Stet.

62.5.5.2.1 Reference 1-2 section 8.1.2.1. VOC handshake

Stet.

62.5.5.2.2 Reference 1-2 section 8.1.2.2. VOC handshake flow charts

Stet.

62.5.5.2.3 Reference 1-2 section 8.1.2.3. Multiple words communication

Stet.

62.5.5.3 Reference 1-2 section 8.1.3. VOC message set

Stet.

62.5.5.3.1 Reference 1-2 section 8.1.3.1. Status messages

Stet.

NOTE: Status message EOC is not expected to be used in implementations of this standard.

62.5.5.3.2 Reference 1-2 section 8.1.3.2. Performance monitoring messages

Stet.

62.5.5.3.3 Reference 1-2 section 8.1.3.3. Configuration messages

Stet,

except in NOTE 6 for Table 17 it should be used: $K=f_c/BSR$, and BSR=16.875. Additionally, specifications for the Transmission profile code (Table 18) is not applicable, and some values of the PSD mask code (Table 19) are regionally specifiic. Some standardized values are specified in Reference 3-2 section 7.5.3.3.1.

62.5.5.3.4 Reference 1-2 section 8.1.3.4. Control messages

Stet.

62.5.6 Link activation and deactivation

The link activation/deactivation process is intended to establish a link with the required transmission parameters between physically connected and powered 10PASS-TS-O and 10PASS-TS-R.

NOTES

1. In this section, for the sake of simplicity, all activation/deactivation processes are described by utilizing the OCC channel only. The same procedures can be arranged over any other OAM channel with similar characteristics.

2. Prior to activation, a G.994.1 handshake procedure is established to recognize the equipment at the customer premises [see Clause 61].

62.5.6.1 Reference 1-2 section 9.1. Link state and timing diagram

The link state and timing diagram is presented in Figure 62–12. States “Power Down” and “Idle”, described in Reference 1-1, do not apply to 10PASS-TS. Procedures “Warm Start” and “Warm Resume”, described in Reference 1-1, do not apply to 10PASS-TS.

62.5.6.1.1 Reference 1-2 section 9.1.2. Activation

Stet.

62.5.6.1.2 Reference 1-2 section 9.1.3. Deactivation

Stet.

62.5.6.1.3 Activation time constants

Time constants determine the activation time, which equals the time interval from the beginning of the activation process until the link reaches the steady-state communication. Time constants shall not exceed the values listed in the Table 62–15.

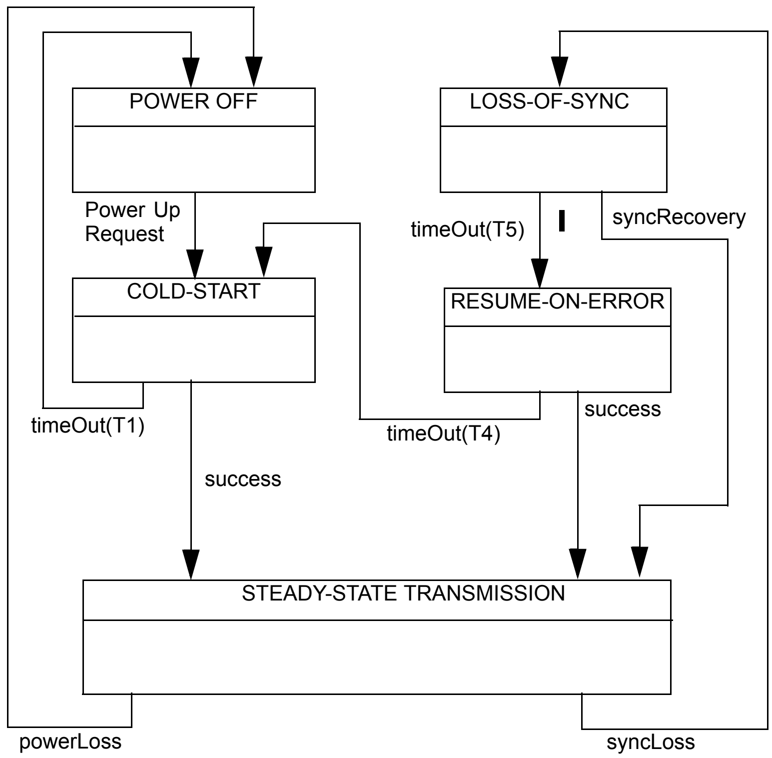


Figure 62–12—Link activation state and timing diagram

Table 62–15—Activation time constants

Process	Time Constant	Maximum value, ms
Cold-Start activation	T1	10000
Resume-on-Error	T4	300
Sync. Loss recovery	T5	200

62.5.6.2 Link transmission parameters

62.5.6.2.1 Modified reference 1-2 section 9.2.1. Set of transmission parameters

Stet,

except
- the parameter range specified in Table 27: the symbol rate granularity is 16.875 kbaud, and the constellation size range is 4-1024.

- the parameter values for Default STP (DF_STP) which may be regionally specific; the currently standardized values are specified in Reference 1-2 section 9.2.1.2, and Reference 3-2 section 8.3.2.2.

62.5.6.2.2 Reference 1-2 section 9.2.2.2. Transmission parameters modification

Stet.

62.5.6.3 Activation/deactivation

62.5.6.3.1 Reference 1-2 section 9.3.1. Functional diagram

Stet.

62.5.6.3.2 Reference 1-2 section 9.3.2. Control signals

Stet.

62.5.6.3.3 Reference 1-2 section 9.3.3. Flags and indicators

Stet.

62.5.6.3.4 Reference 1-2 section 9.3.4. Transmit signals and timers

Stet.

62.5.6.4 Reference 1-2 section 9.3.5. EFM-O state machine

Stet.

62.5.6.5 Reference 1-2 section 9.3.6. EFM-R state machine

Stet.

62.5.6.6 Reference 1-2 section 9.3.6. Two step activation

Stet.

63. Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL

Editors' Notes: *To be removed prior to final publication.*

References:
G.991.2: ITU-T G.shdsl (02/2001)
G.991.2 Amendment 1 (11/2001)
G.994.1 ITU-T G.hs

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):
TC-PAM : Trellis Coded -PAM /
OH: Overhead
TCM: Trellis Coded Modulation
PSD: Power Spectral Density
STU-O: SHDSL Transceiver Unit - Central Office
STU-R : SHDSL Transceiver Unit - Remote
PAM: Pulse Amplitude Modulation
PLL: Phase Lock Loop
SHDSL: Single-pair high-speed digital subscriber line
FSW: Frame Synchronization Word
2-PAM: PAM with 2 levels (start-up)

Revision History:
Draft 1.3 January 2003 Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.414 April 2003 Preliminary draft for IEEE P802.3ah Task Force review

63.1 2BASE-TL Overview

63.1.1 Scope

This clause defines type 2BASE-TL Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) sublayer.

63.1.2 Objectives

The following are the objectives for 2BASE-TL:

a) To provide 2Mb/s encapsulated packet data rate at the α(β) interface.
b) To provide full duplex operation.
c) To provide for operating over non-loaded voice grade twisted pair cable at distances up to 2700 m.
d) To provide a communication channel with a mean bit error rate, at the α(β) interface, of less than one part in 10^7 with 5 dB noise margin.

63.1.3 Relation of 2BASE-TL to other standards

The specifications of the 2BASE-TL PMA and PMD are based on the SHDSL transceiver (PMD and PMS-TC) specified in ITU-T Recommendation G.991.2 “Single-Pair High-Speed Digital Subscriber Line (SHDSL) transceivers”.

63.1.4 Summary of Physical Medium Attachment (PMA) specification

This layer is defined by the α(β) interface and the I-interface. Figure 63–1 shows a functional diagram of the 2BASE-TL PMA layer functionality. The payload is formed into a 2BASE-TL PMA frame with overhead. added (for example, the PMI aggregation Header). The framed data is then scrambled and sent to the PMD sublayer. One distinguishes between the data mode PMA specification which is used during normal data operation and the activation PMA specification which is used when the PMD are training.

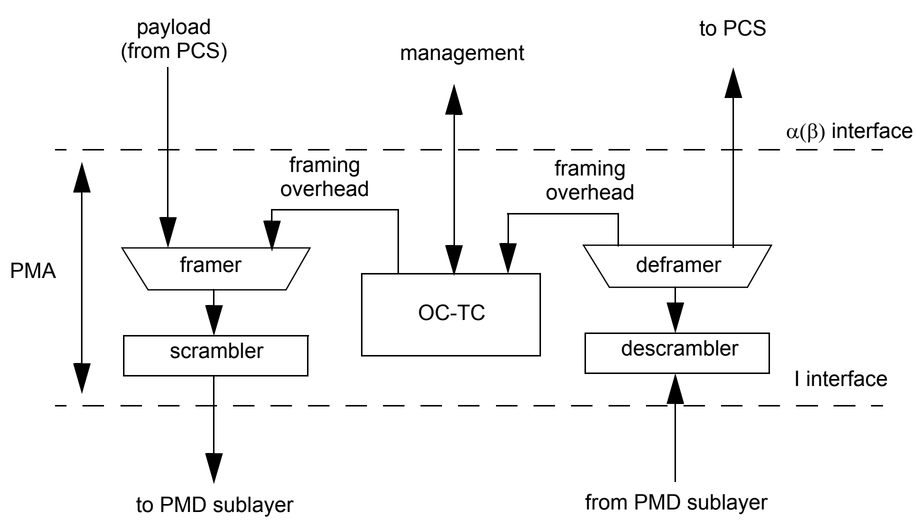


Figure 63–1Diagram of PMA sublayer

63.1.4.1 α(β) Interface

A complete definition of the α(β) interface is contained in 61.2.3.2.

63.1.4.2 The I Interface

The I_O and I_R reference points define interfaces between the PMA and PMD in the 2BASE-TL-O and 2BASE-TL-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flows:

a) Data flow
b) Synchronization flow

The specification of the I interface is implicit in ITU-T Recommendation G.991.2.

63.1.4.2.1 The I Data Flow

The data flow consists of two octet-oriented streams, both with the PMA frame format, with the bit rates defined by the PMD transmission profile:

a) Transmitted data (Tx)
b) Received data (Rx).

If data streams are implemented serially, the MSB of each octet is sent first.

Each stream bit rate value is set during PMD configuration.

63.1.4.2.2 The I Synchronization Flow

The synchronization flow consists of the transmitted and received octet synchronization signals (Clko_t, Clko_r). Optional transmit and receive bit-synchronization signals (Clkp_t, Clkp_r) are defined too.

Synchronization signals are asserted by the PMD and directed towards the PMA.

The synchronization flow signals are described in Table 63–1.

Table 63–1—I Interface signals

Signal(s)	Description	Direction	Notes
Data Signals			
Tx	Transmitted data stream	PMA → PMD	Transmission frame format.
Rx	Received data stream	PMA ← PMD	
Synchronization Signals			
Clko_t	Transmitted octet timing	PMA ← PMD	
Clko_r	Received octet timing	PMA ← PMD	
Clkp_t	Transmitted bit timing	PMA ← PMD	Optional
Clkp_r	Received bit timing	PMA ← PMD	Optional

63.1.4.3 Operation Channel (OC)

The OC-TC function of the PMA shall receive the EOC and overhead indicators over the OC-TC interface. For each 2BASE-TL PMA frame, the OC shall deliver a fixed number of embedded operations channel

(EOC) and overhead indicators bits to the framer. These bits shall be included in the overhead sections of the 2BASE-TL PMA frames.

63.1.5 Summary of Physical Medium Dependent (PMD) specification

The PMD specification is based on Pulse Amplitude Modulation (PAM) and is divided into three consecutive stages, summarized as:

a) Preactivation: during this phase, the PMDs determine each other capabilities and the bit rate they will operate at in data mode. Reference section 6.3.1 (included in this standard per 63.3.2.2) describes the Preactivation reference model. The pre-activation uses G..994.1 as a handshake mechanism to exchange parameters in accordance with the specifications in 61.3. It also offers an optional line probing capability. The line probe uses 2-level PAM signals to determine a suitable bit rate to run at on the copper link.
b) Activation: during this phase, the PMDs train and exchange information necessary to adapt and operate the various filters and processes necessary during data mode operation. Reference section 6.2.1 (included in this standard per 63.3.2.2) describes the Activation reference model. The activation uses 2-level PAM to train the various filters.
c) Data Mode: once pre-activation and activation are complete, the PMD can start transmitting payload data. Reference section 6.1.1 (included in this standard per 63.3.2.2) describes the Data Mode reference model.

63.2 2BASE-TL PMA functional specifications

The 2BASE-TL PMA is specified by incorporating the SHDSL standard, ITU-T Recommendation G.991.2 (02/2001) with the changes specified in G.991.2 Amendment 1 (11/2001), by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ITU-T Recommendation G.991.2 and G.991.2 Amendment 1, will henceforth be referred to as G.991.2.

63.2.1 General exceptions

The 2BASE-TL PMA is precisely the PMS-TC specified in G.991.2, with the following general modifications:

a) There are minor terminology differences between this standard and G.991.2 that do not cause ambiguity. The terminology used in 2BASE-TL was chosen to be consistent with other IEEE 802 standards, rather than with G.991.2. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 63–2.

Table 63–2—Interpretation of general G.991.2 terms and concepts

G.991.2 term or concept	Interpretation for 2BASE-TL
PMS-TC	**PMA**
STU-C, LT	**2BASE-TL-O**
STU-R, NT	**2BASE-TL-R**
Transmission medium dependent interface, U-interface	**MDI**

b) The 2BASE-TL PMA supports only one channel of user data with an associated γ interface.

c) The 2BASE-TL PMA does not support the optional “four-wire mode”. Operation over multiple pairs is optional; if implemented, multi-pair operation shall comply to the specifications in 61.2.2.

d) The 2BASE-TL PMA does not support “plesiosynchronous mode”.

e) The 2BASE-TL PMA shall be byte oriented; hence, the bit oriented parameter i defined for Equation (1) of 63.3.2.1 shall be equal to 0 in all cases.

f) The 2BASE-TL PMA does not support the notion of “sub-blocks” in the Payload Block. Each payload block consists of a contiguous sequence of $12n$ Bytes, with parameter n as defined for Equation (1) .

63.2.2 Specific requirements and exceptions

The 2BASE-TL PMA shall comply to the requirements of G.991.2 Section 7. Where there is conflict between specifications in G.991.2 and those in this standard, those of this standard shall prevail.

Implementation of optional specifications in G.991.2 is not required for compliance with this standard. Reference Section 8 (TPS-TC Layer Functional Characteristics), Reference Section 9 (Management), Reference Annex D (Signal Regenerator Operation), Reference Annex E (Application-specific TPS-TC Framing) and Reference Appendices I, II and III are out of scope for 2BASE-TL PMA.

63.2.2.1 Reference section 7.1

Reference section 7.1.1 (Frame Structure) is replaced with the following:

Table 7-1 of the Reference summarizes the SHDSL frame structure. Complete bit definitions may be found in Reference section 7.1.2. The size of each payload block is defined as k bits, where $k = 96n$. The payload rate r (in kb/s) is given by Equation (1) and Equation (3) of 63.3.2.1, with $i = 0$. The value of n is limited by Equation (2) and Equation (4) of 63.3.2.1.

Reference section 7.1.2.6 (Stuff Indicator bits) is replaced with the following:

2BASE-TL operates in synchronous mode, therefore *sbid1* and *sbid2* are spare bits.

Reference section 7.1.2.7 (Stuffing Bits) is replaced with the following:

2BASE-TL operates in synchronous mode, therefore *stb1* and *stb2* shall be present in every frame, and *stb3* and *stb4* shall not be present.

Reference section 7.1.4 (Frame synchronization) is replaced with the following:

The precise manner in which frame synchronization is acquired or maintained is the choice of the receiver designer. Since different frame synchronization algorithms may require different values for the bits of the FSW, a provision has been made to allow the receiver to inform the far end transmitter of the particular values that is to be used for this field in the transmitted PMS-TC frame.

All other subsections of Reference section 7.1 are referenced *stet*.

63.2.2.2 Reference section 7.2

Stet.

63.3 2BASE-TL PMD functional specifications

The 2BASE-TL PMD (and MDI) is specified by incorporating the SHDSL standard, ITU-T Recommendation G.991.2 (02/2001) with the changes specified in G.991.2 Amendment 1 (11/2001), by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ITU-T Recommendation G.991.2 and G.991.2 Amendment 1, will henceforth be referred to as G.991.2.

63.3.1 General exceptions

The 2BASE-TL PMD is precisely the PMD specified in G.991.2, with the following general modifications:

a) There are minor terminology differences between this standard and G.991.2 that do not cause ambiguity. The terminology used in 2BASE-TL was chosen to be consistent with other IEEE 802 standards, rather than with G.991.2. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 63–3.

Table 63–3—Interpretation of general G.991.2 terms and concepts

G.991.2 term or concept	Interpretation for 2BASE-TL
PMS-TC	**PMA**
STU-C, LT	**2BASE-TL-O**
STU-R, NT	**2BASE-TL-R**
Transmission medium dependent interface, U-interface	**MDI**

b) The 2BASE-TL PMD does not support the optional “four-wire mode”. Operation over multiple pairs is optional; if implemented, multi-pair operation shall comply to the specifications in 61.2.2.

c) The 2BASE-TL PMD does not support “plesiosynchronous mode”.

d) The 2BASE-TL PMD shall be byte oriented; hence, the bit oriented parameter *i* defined for Equation (1) of 63.3.2.1 shall be equal to *0* in all cases.

e) The 2BASE-TL PMD supports the use of the 32-TCPAM constellation for specific rates (see 63.3.2.1).

63.3.2 Specific requirements and exceptions

The 2BASE-TL PMD (including MDI) shall comply to the requirements of G.991.2 Section 5 (Transport Capacity), Section 6 (PMD Layer Functional Characteristics), Section 10 (Clock Architecture), Section 11 (Electrical Characteristics), Section 12 (Conformance Testing). G.991.2 Annex A (Regional Requirements - Region 1), Annex B (Regional Requirements - Region 2) and Annex C (Regional Requirements - Region 3) are regionally applicable, as specified. Where there is conflict between specifications in G.991.2 and those in this standard, those of this standard shall prevail.

Implementation of optional specifications in G.991.2 is not required for compliance with this standard. Reference Section 8 (TPS-TC Layer Functional Characteristics), Reference Section 9 (Management), Reference Annex D (Signal Regenerator Operation), Reference Annex E (Application-specific TPS-TC Framing) and Reference Appendices I, II and III are out of scope for the 2BASE-TL PMD.

63.3.2.1 Reference section 5

Section 5 of G.991.2 is replaced with the following:

This recommendation specifies a two-wire operational mode for 2BASE-TL transceivers that is capable of supporting user (payload) data rates from 192 kb/s to 2.304 Mb/s, using the 16-TCPAM constellation, and 2.368Mb/s to 3.072Mb/s, using the 32-TCPAM constellation. The allowed rates r (in kb/s), using the 16-TCPAM constellation, are given by:

$$r = n \times 64 + i \times 8 \quad (1)$$

where

$$3 \le n \le 36 . \quad (2)$$

The allowed rates r (in kb/s), using the 32-TCPAM constellation, are given by:

$$r = n \times 64 + i \times 8 \quad (3)$$

where

$$36 < n \le 48. \quad (4)$$

In all cases, i is restricted to the value of 0. See 63.3.2.6, 63.3.2.7 and 63.3.2.8 for details of specific regional requirements.

63.3.2.2 Reference section 6

Stet, with the exception of subsection 6.4 (G.994.1 Preactivation Sequence), which is supplanted by 61.3.

Section 6.1.2.3 is superseded by the following text:

Mapper:

The K+1 bits $Y_K(m)$, ..., $Y_1(m)$, and $Y_0(m)$ shall be mapped to a level $x(m)$. In §6.1.2.3 of G.991.2, the mapper function is specified for 16-TCPAM. This text extends that mapping to include both 16- and 32-TCPAM encodings. Table 63–4 shows the bit to level mapping for 16 and 32 level mapping.

63.3.2.3 Reference section 10

Stet, with the exception of Reference Table 10-1, which is replaced by Table 63–5.

63.3.2.4 Reference section 11

Stet.

63.3.2.5 Reference section 12

Stet.

Table 63–4—Mapping of bits to PAM levels

$Y_4(m)$	$Y_3(m)$	$Y_2(m)$	$Y_1(m)$	$Y_0(m)$	32-PAM (5 Bits)	16-PAM (4 Bits)
0	0	0	0	0	-31/32	-15/16
0	0	0	0	1	-29/32	-13/16
0	0	0	1	0	-27/32	-11/16
0	0	0	1	1	-25/32	-9/16
0	0	1	0	0	-23/32	-7/16
0	0	1	0	1	-21/32	-5/16
0	0	1	1	0	-19/32	-3/16
0	0	1	1	1	-17/32	-1/16
0	1	1	0	0	-15/32	1/16
0	1	1	0	1	-13/32	3/16
0	1	1	1	0	-11/32	5/16
0	1	1	1	1	-9/32	7/16
0	1	0	0	0	-7/32	9/16
0	1	0	0	1	-5/32	11/16
0	1	0	1	0	-3/32	13/16
0	1	0	1	1	-1/32	15/16
1	1	0	0	0	1/32	-
1	1	0	0	1	3/32	-
1	1	0	1	0	5/32	-
1	1	0	1	1	7/32	-
1	1	1	0	0	9/32	-
1	1	1	0	1	11/32	-
1	1	1	1	0	13/32	-
1	1	1	1	1	15/32	-
1	0	1	0	0	17/32	-
1	0	1	0	1	19/32	-
1	0	1	1	0	21/32	-
1	0	1	1	1	23/32	-
1	0	0	0	0	25/32	-
1	0	0	0	1	27/32	-
1	0	0	1	0	29/32	-
1	0	0	1	1	31/32	-

Table 63–5—Clock Synchronization Configurations

Mode Number	2BASE-TL-C Symbol Clock Reference	2BASE-TL-R Symbol Clock Reference	Example Application	Mode
3a	Transmit data clock	Received symbol clock	Main application is synchronous transport in both directions.	Synchronous

63.3.2.6 Reference section Annex A

Stet, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

63.3.2.7 Reference section Annex B

Stet, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

63.3.2.8 Reference section Annex C

Stet, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

64. Multi-Point MAC Control

Editor's Notes: To be removed prior to publication

References: (None)

Definitions (to be added to 1.4):

Discovery - Process by which the master (e.g. OLT) finds newly attached active ONU in the PON, and by which the master and slave exchange registration information. The OLT sends a GATE flagged for discovery. The ONU replies with a REGISTER_REQ. The OLT sends a REGISTER and GATE message, and the ONU replies with a REGISTER_ACK. If this sequence is successful, the ONU is registered.

Discovery window - A time period in a given wavelength band reserved by the OLT exclusively for the discovery process.

Downstream - Propagating across an optical access network (OAN) from a network-side interface, or optical line terminal (OLT) towards one or more user-side interfaces, or optical network units (ONUs).

Ethernet passive optical network (EPON) - A passive optical network using Ethernet, as extended by the IEEE 802.3ah standard.

Grant - Permission to transmit at a specific time, for a specific duration. Grants are issued by the OLT (master) to ONUs (slaves) by means of GATE messages.

Logical Link ID (LLID) - A numeric identifier assigned to a link established through the Point-to-Point Emulation sublayer. Each link is assigned a unique LLID. The link is bound to a port at each end station, where a MAC would observe a private link.

Optical Line Terminal (OLT) - The network interface for an optical access network (OAN). The OLT is the master entity in an EPON with regard to the MPCP protocol.

Optical Network Unit (ONU) - A user-side interface to an optical access network (OAN). An ONU is an slave entity in an EPON with regard to the MPCP protocol.

Point-to-point emulation (P2PE) - Emulation of private communication between two end-stations (e.g. ONU) in an EPON. Emulation creates the equivalent of a star topology with the OLT in the nexus, and is required for compliance with IEEE 802.1d bridging.

Ranging - A procedure by which the propagation delay between a master (e.g. OLT) and slave (e.g. ONU) is measured. The round trip delay computation is performed by the OLT, using the timestamp in MPCP messages from the ONU.

Registration - The process by which an ONU and OLT exchange the necessary information to enable the ONU to participate in network exchanges in an EPON.

Round trip time (RTT) - The total transit delay from the master to the slave and back. This is composed of propegation delays through the fiber and electronic hardware.

Single copy broadcast (SCB) - Broadcast distribution of a single transmission, without the need to electronically replicate the transmission. SCB is an intrinsic, or “native,” capability of a PON, where downstream transmissions are passively split and distributed to all ONUs within the PON.

Timestamp - In the context of IEEE 802.3ah, a timestamp is used to synchronize slaves (e.g. ONUs) with the master (OLT) and for the ranging process. Timestamp granularity is 16 bit times, with 32 bit resolution. All MPCP messages passed between OLTs and ONUs contain timestamps.

Upstream - Propagating across an optical access network (OAN) from a user-side interface, or optical network unit (ONU), towards a network-side interface, or optical line terminal (OLT).

Abbreviations (to be added to 1.5):

RTT - Round trip time
LLID - Logical Link ID
OLT - Optical Line Terminal
ONU - Optical Network Unit
P2PE - Point-to-point emulation

Revision History:

Draft 0.9 June 2002, Preliminary draft for IEEE 802.3ah Task Force review
Draft 1.0 August 2002, Initial draft for IEEE 802.3ah Task Force review
Draft 1.1 October 2002, draft for IEEE 802.3ah Task Force review
Draft 1.2 December 2002, draft for IEEE 802.3ah Task Force review
Draft 1.3 January 2003, draft for IEEE 802.3ah Task Force review
Draft 1.414 April 2003, draft for IEEE 802.3ah Task Force review

64.1 Overview

This clause deals with the mechanism and control protocols required in order to reconcile the P2MP topology into the Ethernet framework. The P2MP medium under consideration is a passive optical network (PON) - an optical network with no active elements in the signals' path from source to destination. The only interior elements used in a PON are passive optical components, such as optical fiber, splices, and splitters. When combined with the Ethernet protocol, such a network is referred to as Ethernet Passive Optical Network (EPON).

P2MP is an asymmetrical medium based on a tree (or tree-and-branch) topology. The DTE connected to the trunk of the tree is called Optical Line Terminal (OLT) and the DTEs connected at the branches of the tree are called Optical Network Units (ONU). The OLT typically resides at the service provider's facility, while the ONUs are located at the subscriber premises.

In the downstream direction (from the OLT to an ONU), signals transmitted by the OLT pass through a 1:N passive splitter (or cascade of splitters) and reach each ONU. In the upstream direction (from the ONUs to the OLT), the signal transmitted by an ONU would only reach the OLT, but not other ONUs. To avoid data collisions and increase the efficiency of the subscriber access network, ONU's transmissions are arbitrated. This arbitration is achieved by allocating a transmission window (grant) to each ONU. An ONU defers transmission until its grant arrives. When the grant arrives, the ONU then transmit frames at wire speed during its assigned time slot.

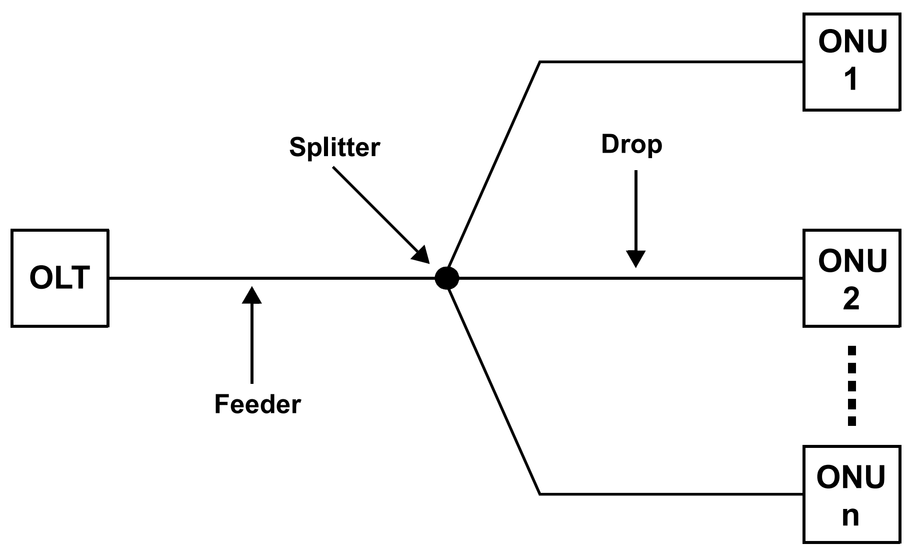


Figure 64–1—PON Topology Example

Topics dealt with in this clause include allocation of upstream transmission resources to different ONUs, discovery and registration of ONUs into the network, and reporting of congestion to higher layers to allow for dynamic bandwidth allocation schemes and statistical multiplexing across the PON.

This clause does not deal with topics including bandwidth allocation strategies, authentication of end-devices, quality-of-service definition, provision, or management.

Each PON consists of a node located at the root of the tree assuming the role of OLT, and multiple nodes located at the tree nodes assuming roles of ONUs. The network operates by allowing only a single ONU to transmit in the upstream direction at a time. Higher layers located at the OLT are responsible for timing the different transmissions. Reporting of congestion by the different ONUs may assist in optimally allocating the bandwidth accross the PON.

Automatic discovery of end stations is performed, culminating in registration through binding of an ONU to a bridge port by allocation of a Logical Link ID (see LLID in #CrossRef# 65.1.3.1.2), and dynamic binding to a MAC connected to the bridge.

This clause specifies the Multi-Point Control Protocol (MPCP) to operate an optical multi-point network by defining a Multi-Point MAC Control sublayer as an extension of the MAC Control sublayer defined in Clause 31, and supporting current and future operations as defined in Clause 31 and annexes.

64.1.1 Goals and objectives

The goals and objectives of this clause are the definition of a point-to-multi-point Ethernet network utilizing an optical medium.

Specific objectives met include:

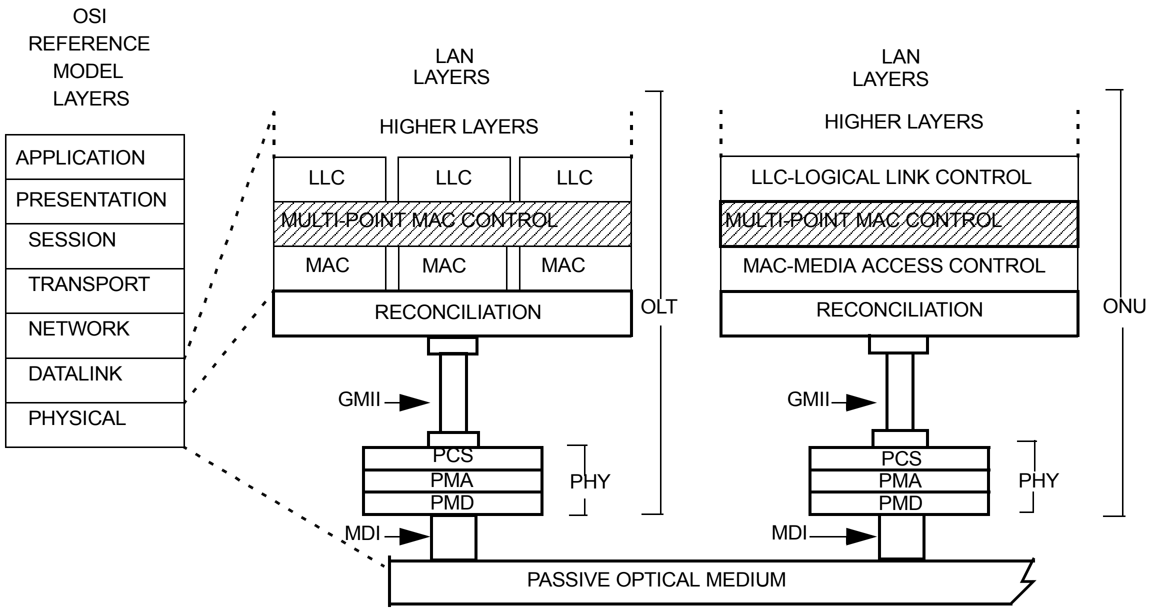
a) Support of Point to Point Emulation (P2PE) as specified
b) Support multiple LLIDs and MAC Clients at the OLT
c) Support a single LLID per ONU
d) Support a mechanism for single copy broadcast
e) Flexible architecture allowing dynamic allocation of bandwidth
f) Disclosure of PMD receiver parameters allowing flexibility in design of PMD
g) Use of 32 bit timestamp for timing distribution
h) MAC Control based architecture
i) Ranging of discovered devices for improved network performance
j) Continuous ranging for compensating round trip time variation

64.1.2 Position of Multi-Point MAC Control within the IEEE 802.3 hierarchy

Multi-Point MAC Control defines the MAC control operation for optical multi-point networks. Figure 64–2 depicts the architectural positioning of the Multi-Point MAC Control sublayer with respect to the MAC and the MAC Control client. The Multi-Point MAC Control sublayer takes the place of the MAC Control sub-layer to extend it to support multiple clients and additional MAC control functionality.

Multi-Point MAC Control is defined using the mechanisms and precedents of the MAC Control sublayer. The MAC Control sublayer has extensive functionality designed to manage the real-time control and manipulation of MAC sublayer operation. This clause specifies the extension of the MAC Control mechanism to manipulate multiple underlying MACs simultaneusly. This clause also specifies a specific protocol implementation for MAC Control.

The Multi-Point MAC Control protocol is specified such that it can support new functions to be implemented and added to this standard in the future. Multi-Point Control Protocol (MPCP), the management protocol for P2MP is one of these protocols. Non-realtime, or quasistatic control (e.g., configuration of MAC operational parameters) is provided by Layer Management. Operation of the Multi-Point MAC Control sub-layer is transparent to the MAC.



GMII = GIGABIT MEDIA INDEPENDANT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINATION
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 64–2—Relationship of Multi-Point MAC Control and the OSI protocol stack

Implementation of Multi-Point MAC Control is mandatory for subscriber access devices containing point-to-multipoint physical layer devices defined in #CrossRef# Clause 58, and optional for all other IEEE 802.3 devices.

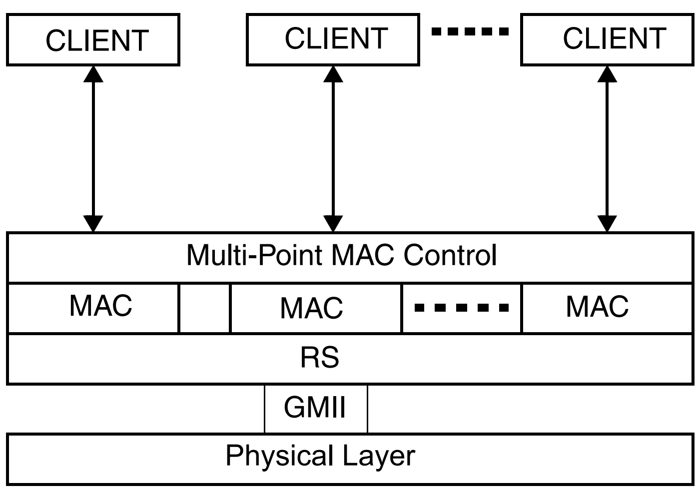


Figure 64–3—System Layer Diagram

Editor's Note*: Figure 64-3 maybe not required anymore.*

As depicted in Figure 64–3, the layered system instantiates multiple MAC entities, using a single physical layer. The individual MAC instances offer a Point-to-point emulation service between the OLT and the ONU. An additional MAC is instantiated to communicate to all ONUs at once. This instance takes maximum advantage of the broadcast nature of the downstream channel by sending a single copy of a frame that is received by all ONUs. This MAC instance is referred to as Single Copy Broadcast (SCB).

The ONU only requires one MAC instance since frame filtering operations are done at the RS layer before reaching the MAC. Therefore, MAC and layers above are emulation agnostic at the ONU (see #CROSS-REF# 65.1.3.2).

64.1.3 Functional block diagram

Figure 64–4 provides a functional block diagram of the Multi-Point MAC Control architecture.

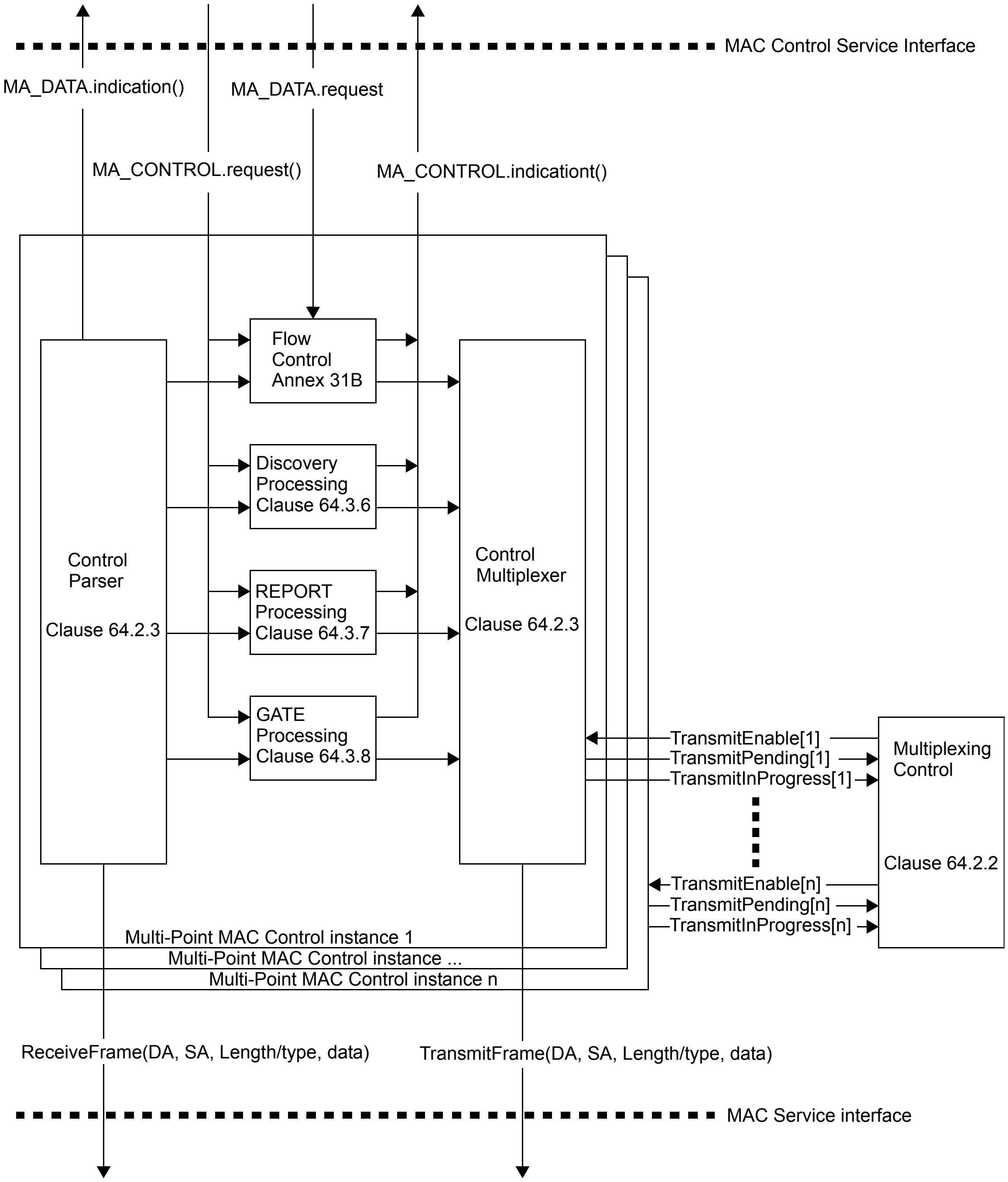


Figure 64–4—Multi-Point MAC Control Functional Block Diagram

64.1.4 State diagram conventions

The body of this standard comprises state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2 augmented as follows:

a) [start x_timer, y] sets expiration of *y* to timer *x_timer*.
b) [stop x_timer] aborts the timer operation for *x_timer* asserting *x_timer_not_done* indefinitely.

64.2 Multi-Point MAC Control operation

As depicted in Figure 64–4, the Multi-Point MAC Control functional block comprises the following functions:

a) *Multiplexing Control*. This blocks is responsible for synchronizing Multi-Point MAC Control instances associated with the Multi-Point MAC Control. This block maintains the Multi-Point MAC Control state and controls the multiplexing functions of the instantiated MACs.
b) *Multi-point MAC Control Instance n*. This block is instantiated for each MAC and respective clients (MAC, MAC Control) associated with the Multi-Point MAC Control. It holds all the variables and state associated with operating all MAC Control protocols for the instance.
c) *Control Parser*. This block is responsible for parsing MAC Control frames, and interfacing with Clause 31 entities, the OMP block, and the MAC Client.
d) *Control Multiplexer*. This block is responsible for selecting the source of the forwarded frames.
e) *Clause 31 annexes*. This block holds MAC Control actions as defined in Clause 31 annexes for support of legacy and future services.
f) *Optical Multi-Point (OMP)*. This block is responsible for handling the MPCP in the context of the MAC.

64.2.1 Principles of Multi-Point MAC Control

As depicted in Figure 64–4, Multi-Point MAC Control sublayer may instantiate multiple Multi-Point MAC Control instanses in order to interface multiple MAC and MAC Control clients above with multiple MACs below. A unique unicast MAC instance is used at the OLT to communicate with each ONU. The individual MAC instances utilize the point-to-point emulation service between the OLT and the ONU as defined in #Cross Ref# Clause 65.

At the ONU, a single MAC instance is used to communicate with a MAC instance at the OLT. In that case, the Multi-Point MAC Control contains only a single instance of the Control Parser/Multiplexer function.

Multi-Point MAC Control protocol supports several MAC and client interfaces. Only a single MAC interface and Client interface is enabled for transmission at a time. There is a tight mapping between a MAC service interface and a Client service interface. In particular, the assertion of the ReceiveFrame interface in MAC *j* enables the indication interface of Client *j*. Conversely, the assertion of the request service interface in Client *i* enables the TransmitFrame interface of MAC *i*. Note that the Multi-Point MAC sublayer need not receive and transmit packets associated with thes same interface at the same time. Thus the Multi-Point MAC Control acts like multiple MAC Controls bound together with common elements.

The scheduling algorithm is implementation dependent, and is not specified for the case where multiple transmit request happen at the same time.

The reception operation is as follows. The Multi-Point MAC Control instance generates ReceiveFrame function calls continuously to the underlying MAC instances. Since these MACs are receiving frames from a single PHY only one frame is passed from the MAC instances to Multi-Point MAC Control. The MAC instance responding to the ReceiveFrame is referred as the enabled MAC, and its service interface is referred as the enabled MAC interface. The MAC passes to the Multi-Point MAC Control sublayer all valid frames. Invalid frames, as specified in 3.4, are not passed to the Multi-Point MAC Control sublayer in response to a ReceiveFrame function call.

The enabling of a transmit service interface is performed by the Multi-Point MAC Control instance in collaboration with the Multiplexing Control. Frames generated in the MAC Control are given priority over MAC Client frames, in effect, prioritizing the MA_CONTROL primitive over the MA_DATA primitive, and for this purpose MA_DATA.request primitives may be delayed, discarded or modified in order to perform the requested MAC Control function. For the transmission of this frame, the Multi-Point MAC Control instance enables forwarding by the MAC Control functions, but the MAC Client interface is not enabled. The reception of a frame in a MAC enables the ReceiveFrame interface of the MAC. Only one receive MAC interface will be enabled at any given time since there is only one PHY interface.

The information of the enabled interfaces is stored in the controller state variables, and accesed by the Multiplexing Control block.

The Multi-Point MAC Control sublayer uses the services of the underlying MAC sublayer to exchange both data and control frames. Implementation of the Multi-Point MAC Control sublayer is mandatory for optical multi-point networks, however, a MAC Control client cannot assume the existence of additional MAC Control functions, as defined in Clause 31 annexes, in a remote DTE.

Receive operation at each instance:

a) A frame is received from the underlying MAC.
b) The frame is parsed according to Length/Type field
c) MAC Control frames are demultiplexed according to opcode and forwarded to the relevant processing functions
d) Data frames are forwarded to the MAC Client by asserting MA_DATA.indication primitives

Transmit operation at each instance:

a) The Client signals a frame transmission by asserting MA_DATA.request,
b) or a protocol processing block attempts to issue a frame, as a result of a previous MA_CONTROL.request or as a result of an MPCP event that generates a frame.
c) When allowed to transmit by the Multiplexing Control block, the frame is forwarded.

64.2.2 Multiplexing Control

The Multiplexing Control block is responsible for transmitting only one frame at a time out of Multi-point MAC Control sub-layer. It enables the transmission of only one MAC interface such that all other instances can not transmit any frames. Therefore, only one transmitEnable signal can be enabled at a time. The purpose of the Multiplexing Control is to allow only one of the multiple clients to transmit to the RS layer at any one time.

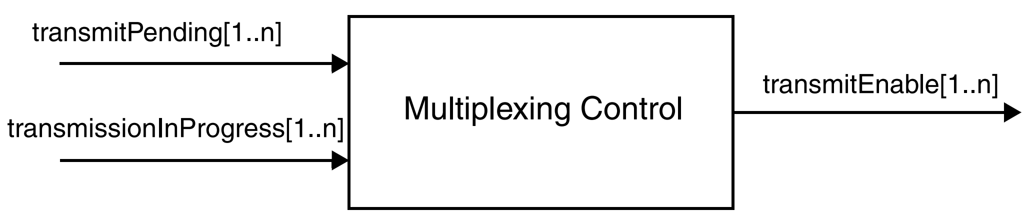


Figure 64–5—Multiplexing Control Service Interfaces

Multi-Point MAC Control Instance n function block communicates with the Multiplexing Control using transmitEnable[n] and transmissionInProgress[n] state variable (see Figure 64–5)

64.2.2.1 Constants

No constants are defined for the Multiplexing Control functional block.

64.2.2.2 Variables

BEGIN

This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.

TYPE: boolean
DEFAULT VALUE: true

transmitEnable[j]

These variables are used to control the transmit path in a Multi-Point MAC Control instance. Setting them to on indicates that the selected instance is permitted to transmit a frame. Setting it to off will inhibit the transmission of further frames in the selected instance. Only one of transmitEnable[j] should be set to on at a time.

TYPE: boolean
DEFAULT VALUE: false (for OLT)
true (for ONU)

transmissionInProgress[j]

This variable indicates that the Multi-Point MAC Control instance *j* is in the TransmitFrame state.

TYPE: boolean
DEFAULT VALUE: false

transmitPending[j]

These variables are used to indicate that an instance is ready to forward a frame. Setting them to DATA or CONTROL indicates that the selected instance is ready to transmit data of MAC Control frame respectively.

TYPE: enum - possible values are: NONE, DATA, CONTROL
DEFAULT VALUE: NONE

64.2.2.3 Functions

select

This function is used to select the next instance to be allowed to change to the forwarding state. The function returns an index to the transmitPending array for which the value is not NONE. The selection criteria in the presence of multiple active elements in the list is implementation dependent.

64.2.2.4 Timers

No timers are defined for the Multiplexing Control functional block.

64.2.2.5 Messages

No messages are defined for the Multiplexing Control functional block.

64.2.2.6 State Diagram

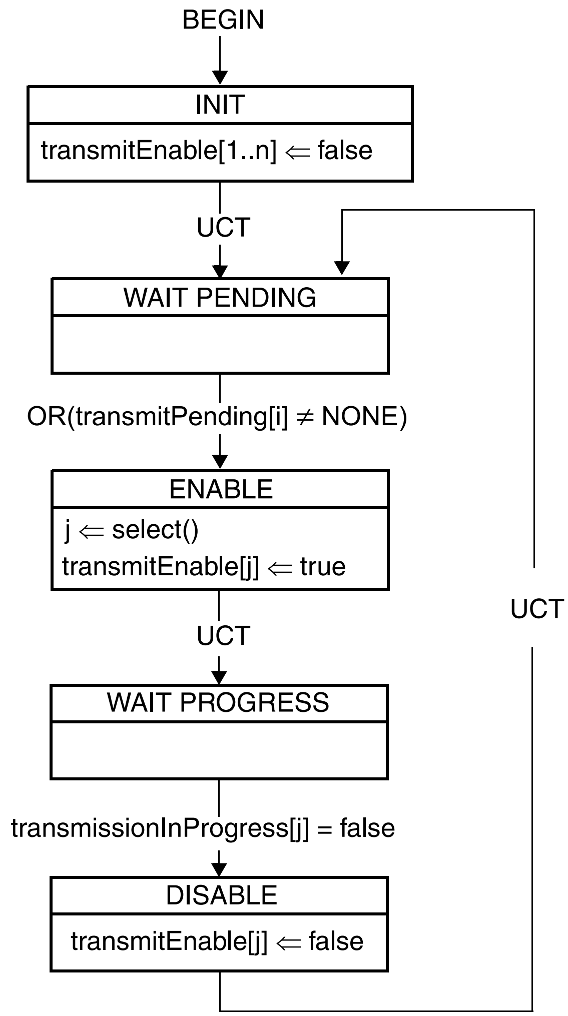


Figure 64–6—Multiplexing Control state diagram

64.2.3 Control Parser/Multiplexer

The Control Parser is responsible for opcode independent parsing of MAC frames in the reception path. By identifying MAC Control frames, demultiplexing into multiple entities for event handling is possible. Interfaces are provided to existing Clause 31 entities, functional blocks associated with MPCP, and the MAC Client.

The Control Multiplexer is responsible for forwarding frames from the MAC Control opcode specific functions and the MAC Client to the MAC. Multiplexing is performed in the transmission direction. Given multiple MA_DATA.request from the MAC Client, and MA_CONTROL.request from the MAC Control Clients, a single TransmitFrame is generated for transmission. At the OLT, multiple MAC instances share the same Multi-Point MAC Control, as a result, the transmit block is enabled based on an external control signal housed in Multiplexing Control for transmission overlap avoidance. At the ONU the Gate Processing functional block interfaces for upstream transmission administration.

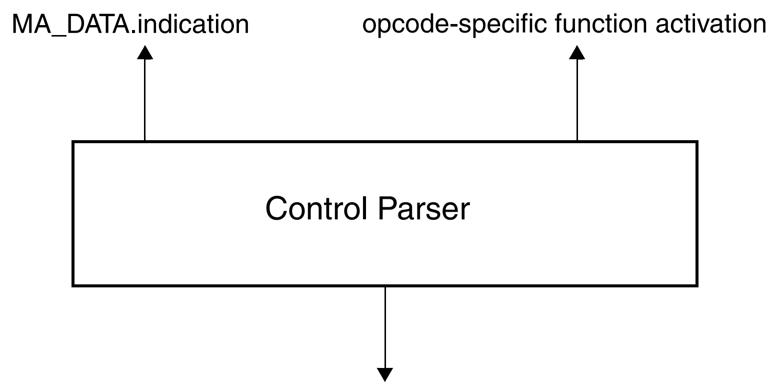


Figure 64–7—Control Parser Service Interfaces

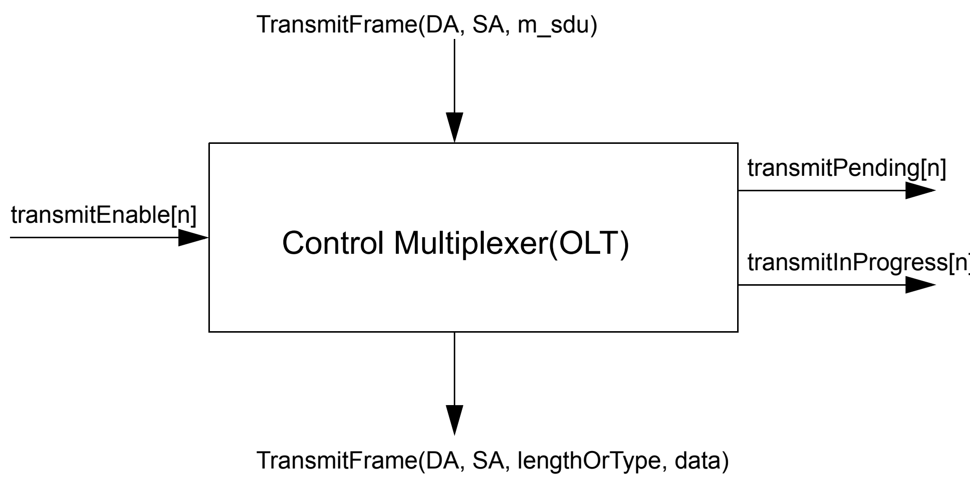


Figure 64–8—OLT Control Multiplexer Service Interfaces

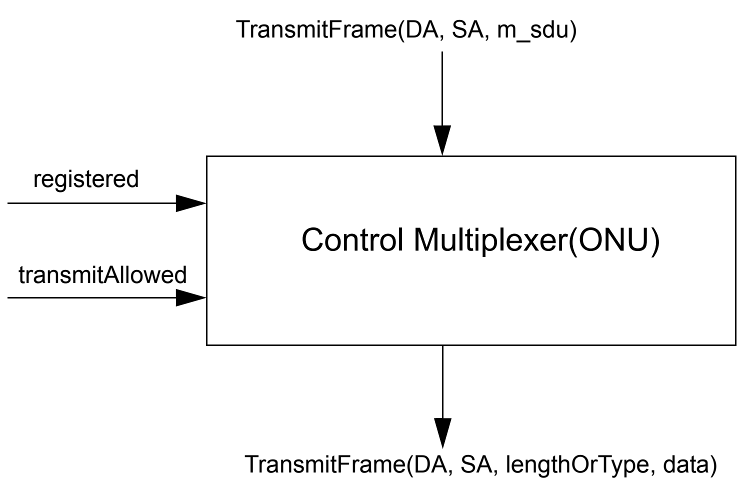


Figure 64–9—ONU Control Multiplexer Service Interfaces

64.2.3.1 Constants

guard_threshold

This constant holds the maximal amount of drift allowed for a timestamp.
TYPE: integer
VALUE: 4

tail_guard

This constant holds the value used to reserve space at the end of the uplink transmission at the ONU in addition to the last frame m_sdu.
Space is reserved for the MAC overheads including: preamble (8 bytes), DA (6 bytes), SA (6 bytes), FCS (4), and PCS trailer (3 bytes for /T/R/R/).
TYPE: integer
DEFAULT VALUE: 30

MAC Control

The value of the length type field as defined in #CrossRef# subclause 31.4.1.3.
TYPE: integer
DEFAULT VALUE: 0x8808

64.2.3.2 Variables

BEGIN

This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.
TYPE: boolean
DEFAULT VALUE: true

transmitAllowed

This variable is used to control PDU forwarding in the transmit path. It is set to *true* when the transmit path is enabled, and is set to *false* when the transmit path is being shut down. *transmitAllowed* is not used at the OLT, but changes its value according to the state of the Gate Processing functional block for the ONU.
TYPE: boolean
DEFAULT VALUE: false

localTime

This variable holds the value of the local counter used to control OMP operation. This variable is advanced by a timer at 62.5MHz, and counts in time_quanta. It is periodically reset by the OMP sublayer on notification of the existence of a more accurate timebase.
Changing the value of this variable while running using Layer Management is highly undesirable and is unspecified.
TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-00

timestampError

This variable is used to indicate whether an error is signaled resulting due to uncorrectable timestamp drift.
TYPE: boolean
DEFAULT VALUE: false

RTT

This variable holds the calculated Round Trip Time to the ONU.
TYPE: 16 bit unsigned
DEFAULT VALUE: FF-FF

stopTime

This variable holds the value of the local counter at the end of the nearest grant.
TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-00

registered

This variable holds the current value result of the Discovery Process. It is set to true once discovery is complete, and registration is acknowledged.

TYPE: boolean
DEFAULT VALUE: false

transmitEnable

This variable is used to control the transmit path in a Multi-Point MAC Control instance. Setting it to on indicates that the selected instance is permitted to transmit a frame. Setting it to off will inhibit the transmission of further frames in the selected instance.

TYPE: boolean
DEFAULT VALUE: false

transmitPending

This variable is used to indicate that the instance is ready to forward a frame. Setting it to DATA or CONTROL indicates that the instance is ready to transmit a frame. Each instance is aware by receiving MA_DATA.request, or MA_Control.request primitive.

TYPE: enum - possible values are: NONE, DATA, CONTROL
DEFAULT VALUE: NONE

transmissionInProgress

This variable indicates that a Multi-Point MAC Control instance is in the TransmitFrame state.

TYPE: boolean
DEFAULT VALUE: false

64.2.3.3 Functions

timestamp(m_sdu, time)

m_sdu[4..7] = time

sizeof(m_sdu)

This function returns the size of the m_sdu in bytes.

ReceiveFrame

The MAC Sublayer primitive called to receive a frame with the specified parameters.

TransmitFrame

The MAC Sublayer primitive called to transmit a frame with the specified parameters.

64.2.3.4 Timers

No timers are defined for the Control Parser or Control Multiplexer functional block.

64.2.3.5 Messages

MA_DATA.request(DA, SA, m_sdu)

The service primitive used by a client to request the MAC to transmit a frame.

MA_DATA.indication(DA, SA, m_sdu)

The service primitive used by the MAC to signal the client an arriving frame.

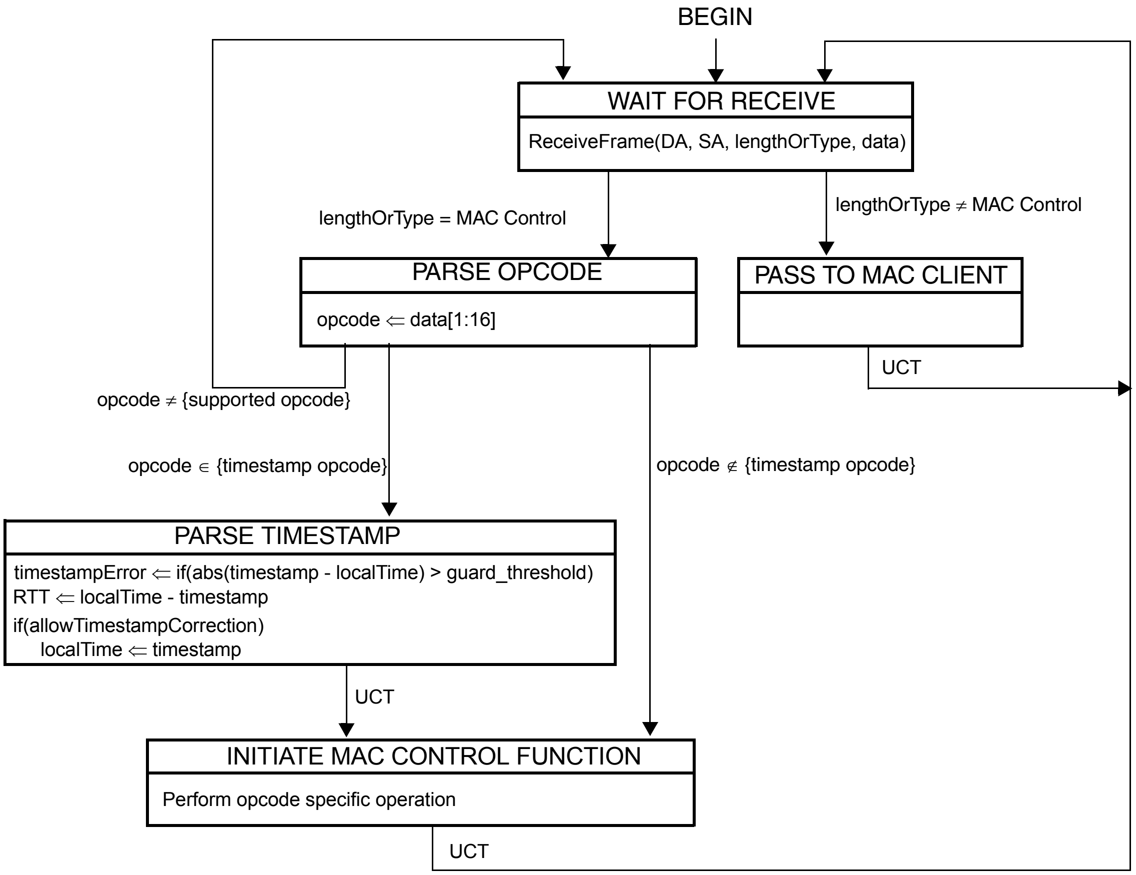
MA_CONTROL.request(DA, opcode, request operand list)

The service primitive used by a client to request a MAC Control sublayer function with the specified request_operands.

MA_CONTROL.indication(opcode, indication operand list)

The service primitive used by MAC Control sublayer to signal the client an event with specified parameters.

64.2.3.6 State Diagram



NOTE: The opcode-specifc operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state machine (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Figure 64–10—Control Parser state diagram

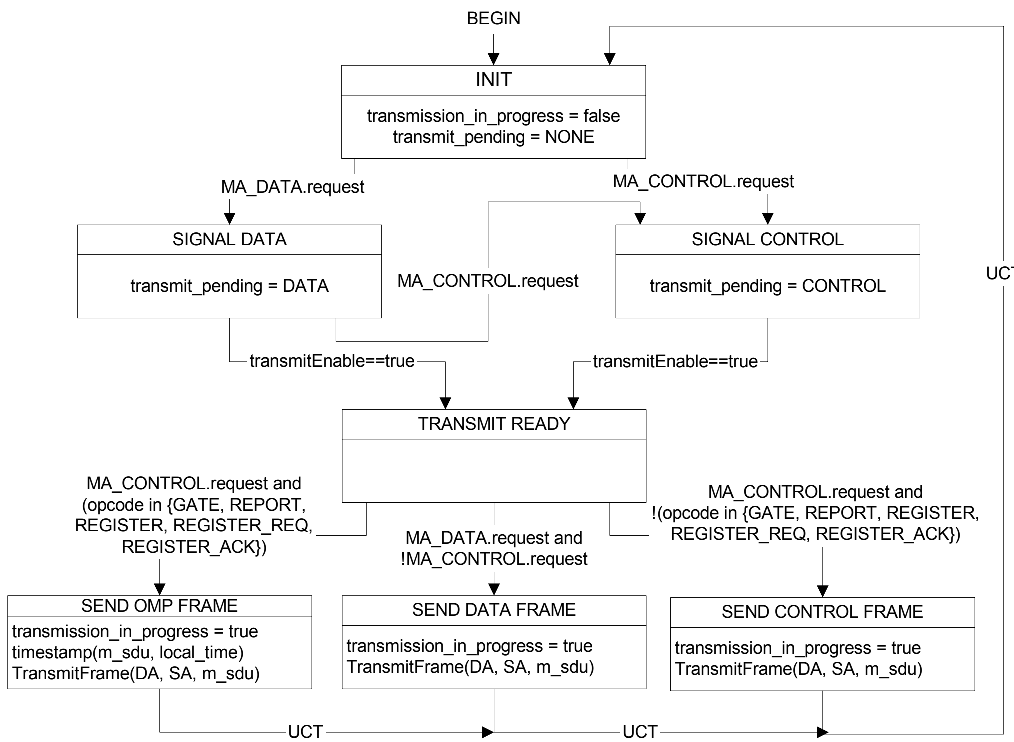


Figure 64–11—OLT Control Multiplexer state diagram

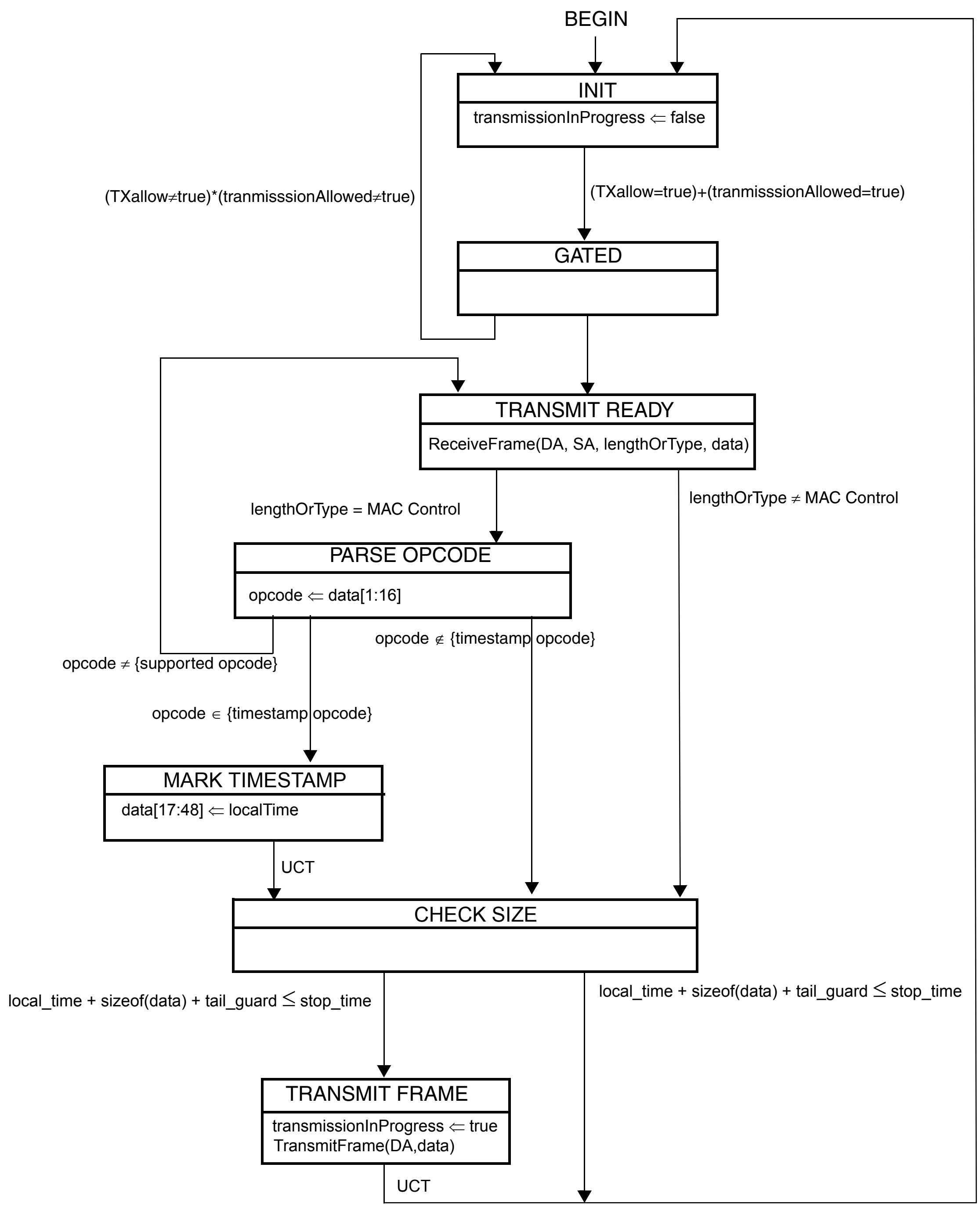


Figure 64–12—Control Multiplexer state diagram

64.3 Optical Multi-Point operation

As depicted in Figure 64–4, the Optical Multi-Point functional block comprises of the following functions:

a) *OMP Parser/Multiplexer*. This block parses the different opcodes as defined in the MPCP protocol from/into the different control blocks.

b) *Discovery Processing*. This block manages the discovery process, through which an ONU is discovered and registered with the network while compensating for RTT.
c) *Report Processing*. This block manages the generation and collection of report messages, through which bandwidth requirements are broadcast in the network.
d) *Gate Processing*. This block manages the generation and collection of gate messages, through which multiplexing of multiple transmitters is achieved.
e) *State Variables*. Holding information required to operate the network and maintain the MPCP protocol.

As depicted in Figure 64–4, the layered system may instantiate multiple MAC entities, using a single physical layer. Each instantiated MAC communicates with an instance of the OMP functional block through the Multi-Point MAC Control. In addition some global variables are shared accross the multiple instances. Common state control is used to synchronize the multiple MACs using OMP procedures. Operation of the common state control is generally considered outside the scope of this document.

64.3.1 Principles of Optical Multi-Point

Optical Multi-Point allows a MAC Client to participate in a point-to-multi-point optical network. Transmitting and receiving frames as if it was connected to a dedicated link. In doing so, it employs the following principles and concepts:
a) A MAC client transmits and receives frames through the Multi-Point MAC Control sublayer.
b) The Multi-Point MAC Control decides when to allow a frame to be transmitted using the client interface Control Multiplexer.
c) Given a transmission opportunity, the MAC Control may generate control frames that would be transmitted in advance of the MAC Client's frames, utilizing the inherent ability to provide higher priority transmission of MAC Control frames over MAC Client frames.
d) Multiple MACs may share the same media by allowing only a single MAC to transmit at any given time across the network.
e) Such gating of transmission is orchestrated through the Gate Processing function.
f) New devices are discovered in the network and allowed transmission through the Discovery Processing function.
g) Fine control of the network bandwidth distribution can be achieved using feedback mechanisms supported in the Report Processing function.
h) When operated, the network is assymetrical, with the station connected to the network feeder assuming the role of master, and the station connected to the node assuming the role of slave.

64.3.2 Service interfaces

The MAC Client communicates with the Control Multiplexer using the standard service interface specified in Clause 2.3. Optical Multi-Point communicates with the underlying MAC sublayer using the standard service interface specified in Clause 4.3.2. Similarly, Optical Multi-Point communicates internally using primitives and interfaces consistant with definitions in Clause 31.

An additional interface is exported towards the MAC and Physical layer in order to enable and disable the lasing at the PMD.

Editor's note*: To be removed prior to publication. This interface will probably be based on exposing the relevant variable through Layer Management.*

64.3.3 MPCP Theory of operation

64.3.3.1 MPCP Gate Process

(1) OLT

- Normal case

At the OLT, the WAIT state is the initial state of the Gate Process. In this state, the Gate Process waits for the MA_CONTROL.request primitive from the client or the Discovery Process. The MA_CONTROL.request primitive contains the contents of GATE message to be sent. When the Gate Process receives the MA_CONTROL.request primitive, it transits to the SEND GATE state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the GATE message and starts the periodic_timer. Then, it transits to the WAIT state. This is the normal case.

- Expiration of periodic_timer

The Gate Process uses the periodic_timer to send the GATE messages at certain intervals. The Gate Process starts this timer whenever it issues the OMP.request primitive indicating the GATE message. At the expiration of periodic timer in the WAIT state, the Gate Process transits to the PERIODIC TRANSMISSION state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the GATE message with no grant and starts the periodic_timer. Then, it transits to the WAIT state.

- Completion of Discovery procedure

At the completion of Discovery procedure, the Gate Process transits to the PERIODIC TRANSMISSION state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the GATE message with no grant and starts the periodic_timer. Then, it transits to the WAIT state.

(2) ONU

The ONU maintains two states in the Gate Process. One is the Programming state, another is the Activation state.

Programming state

The WAIT state is the initial state of the Programming state. In this state, the Gate Process waits for the OMP.indication primitive from the OMP Parser. The OMP.indication primitive contains the contents of GATE message received from the OLT. When the Gate Process receives the OMP.indication primitive, it transits to the INCOMING GRANT state. In this state, it delineates maximum four grants from the primitive, issues the MA_CONTROL.indication primitive to inform the client of grants and adds these grants to the list of grants. In this list, grants which will be treated in the future are listed. If the specified start time of the delineated grant is the past, this grant is ignored. Then, it transits to the WAIT state.

Activation state

- Normal case

The SORT state is the initial state of the Activation state. In this state, it gets the grant with the smallest start_time value from the list and begins to treat this grant. If the length of the grant is enough, it transits to the SET START TIMER state. In this state, the Gate Process starts the grant_start_timer to detect the beginning of grant. After this timer expires, it transits to the TURN LASER ON state. In this state, it makes the laser on, removes the grant from the list and starts the IDLE_timer to detect the end of the IDLE period. After this timer expires, it transits to the START TX state. In this state, it enables the transmission of frames, issues the MA_CONTROL.indication primitive to inform the client of the effective grant and starts the grant_window_timer to detect the end of effective grant. After this timer expires, it transits to the STOP TX state. In this state, it makes laser off, disables the transmission of frames and issues the MA_CONTROL.indication primitive to inform the client of the end of effective grant. Then it transits to the SORT state and begins to treat the next grant in the list.

- Too short length of grant

If the length of the grant is too short in the SORT state, the Gate Process transits to the REMOVE LIST state. In this state, it removes this grant from the list and transits to the SORT state.

- No grant

While the list of grants is empty in the SORT state, the Gate Process stays in the SORT state.

64.3.3.2 MPCP Discovery Process

(1) OLT

The OLT maintains three states in the Discovery Process. They are the Window Setup state, the Process Request state and the Final Registration state.

Window Setup state

The IDLE state is the initial state of the Window Setup state. In this state, the Discovery Process waits for the MA_CONTROL.request primitive from the client. The MA_CONTROL.request primitive contains the discovery grant and the length of discovery window. When the Discovery Process receives the MA_CONTROL.request primitive, it transits to the SEND REGISTER WINDOW state. In this state, it issues the MA_CONTROL.request primitive to the Gate Process to send the Discovery GATE message and starts the wait_for_window timer to detect the beginning of the discovery window. After this timer expires, it transits to the INSIDE REGISTER WINDOW state. In this state, it starts the register_window_timer to detect the end of the discovery window. After this timer expires, it transits to the IDLE state.

Process Request state

The IDLE state is the initial state of the Process Request state. At the beginning of the discovery window, the Discovery Process transits to the ACCEPT REGISTER REQUEST state. When it receives the OMP.indication primitive indicating the REGISTER_REQ message in this state, it transits to the SIGNAL state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of the receipt of the REGISTER_REQ message. Then, it transits to the ACCEPT REGISTER REQUEST state. At the end of the discovery window, it transits to the IDLE state.

Final Registration state

- Normal registration

The ILDE state is the initial state of the Final Registration state. When the Discovery Process receives the MA_CONTROL.request primitive indicating the REGISTER message in this state, it transits to the REGISTER state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the REGISTER message with the success flag. Then, it transits to the WAIT for REGISTER_ACK state. In this state, it starts the ONU_timer to monitor the REGISTER_ACK message from the ONU. If it receives the OMP.indication primitive indicating the REGISTER_ACK message from the OMP Parser before the expiration of the ONU_timer, it transits to the COMPLETED DISCOVERY state. In the COMPLETE DISCOVERY state, it checks the flag in the REGISTER_ACK message. If the flag indicates the success, the Discovery Process transits to the REGISTERED state. In the REGISTERED state, it issues the MA_CONTROL.indication primitive to inform the client of the success of registration.

- Rejection of requested registration

When the Discovery Process rejects the requested registration, it issues the OMP.request primitive to the OMP Multiplexer to send the REGISTER message with the nack flag. Then, it transits to the IDLE state.

- Expiration of ONU_timer

If the ONU_timer expires in the WAIT for REGISTER_ACK state, the Discovery Process transits to the DEREGISTER state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of the failure of registration and issues the OMP.request primitive to send the REGISTER message with the de-register flag. Then, it transits to the IDLE state.

- REGISTER_ACK with failure flag

If the flag in the REGISTER_ACK message indicates the failure, the Discovery Process transits to the DEREGISTER state. The sequential behavior is same as the expiration of ONU_timer case.

- De-registration from ONU

When the Discovery Process receives the MA_CONTROL.request primitive requesting de-registration in the REGISTERED state, it transits to the DEREGISTER state. The sequential behavior is same as the expiration of ONU_timer case.

- Expiration of omp_timer

When the omp_timer expires in the REGISTERED state, the Discovery Process transits to the DEREGISTER state. The sequential behavior is same as the expiration of ONU_timer case.

- De-registration from OLT

When the Discovery Process receives the OMP.indication primitive indicating the REGISTER_REQ message with the de-register flag, it transits to the DEREGISTER state. The sequential behavior is same as the expiration of ONU_timer case.

- Re-registration

When the Discovery Process receives the MA_CONTROL.request primitive requesting the re-registration, it issues the OMP.request primitive to the OMP Multiplexer to send the REGISTER message with the re-registration flag. Then, it transits to the WAIT for REGISTER_ACK state. The sequential behavior is same as the normal registration case.

(2) ONU

The ONU maintains two states in the Discovery Process. One is the Window Setup state, another is the Process state.

Window Setup state

- Broadcast DA

The WAIT state is the initial state of the Window Setup state. In this state, the Discovery Process disables the transmission of frames and makes the laser off. When the Discovery Process receives the OMP.indication primitive from the OMP Parser indicating the GATE message with the discovery flag, it transits to the CHECH UNICAST state. In this state, it checks the DA. If the DA is not the unicast address, it transits to the WAIT FOR WINDOW state. In this state, it starts the wait_for_window_timer to detect the beginning of discovery grant. After this timer expires, it transits to the RANDOM WAIT state. In the RANDOM WAIT state, it starts the random_delay_timer to perform the random delay process. After this timer expires, it transits to the TURN LASER ON state. In this state, it makes the laser on and starts the IDLE_timer to detect the beginning of the effective grant. After this timer expires, it transits to the INSIDE REGISTER WINDOW state. In this state, it enables the transmission of frames and starts the grant_window_timer to detect the end of the effective grant. After this timer expires, it transits to the WAIT state.

- Unicast DA

If the DA in the OMP.indication primitive is the unicast address, Discovery Process transits to the WAIT for WINDOW UNICAST state. In this state, it starts the wait_for_window_timer to detect the beginning of discovery grant. After this timer expires, it transits to the TURN LASER ON state. The sequential behavior is same as the broadcast DA case.

(Note) "MA_CONTROL.request()" just below the WAIT state is replaced with "OMP.indication()".

Process state

- Normal registration

The WAIT state is the initial state of the Process state. When the Discovery Process receives the MA_CONTROL.request primitive requesting the registration from the client, it transits to the REGISTERING state. At the beginning of the effective grant, it transits to the REGISTER_REQ state. In this state, it issues the OMP.request primitive indicating the REGISTER_REQ message to the OMP Multiplexer and starts the wait_for_register_msg_timer to monitor the REGISTER message from the OLT. If it receives the OMP.indication primitive indicating the REGISTER message with the success flag before the expiration of the wait_for_register_msg_timer, it transits to the ACK state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of the acceptance of registration and issues the OMP.request primitive indicating the REGISTER_ACK message with the success flag to the OMP Multiplexer. Then, it transits to the REGISTERED state.

- Rejection of requested registration

In the REGISTER_REQ state, if the Discovery Process receives the OMP.indication primitive indicating the REGISTER message with the nack flag before the expiration of the wait_for_register_msg_timer, it transits to the NACK state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of the rejection of registration and issues the OMP.request primitive indicating the REGISTER_ACK message with the failure flag to the OMP Multiplexer. Then, it transits to the WAIT state.

- Expiration of wait_for_register_msg_timer

If the wait_for_register_msg_timer expires in the REGISTER_REQ state, the Discovery Process transits to the TIMEOUT state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of the retry of registration. Then, it transits to the REGISTERING state.

- Re-registration

When the Discovery Process receives the OMP.indication primitive indicating the REGISTER message with the re-registration flag in the REGISTERED state, it transits to the ACK state. The sequential behavior is same as the normal registration case.

- De-registration from OLT

When the Discovery Process receives the OMP.indication primitive indicating the REGISTER message with the de-registration flag in the REGISTERED state, it transits to the REMOTE DEREGISTER state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of de-registration. Then, it transits to the WAIT state.

- De-registration from ONU

When the Discovery Process receives the MA_CONTROL.request primitive requesting de-registration from the client in the REGISTERED state, it transits to the LOCAL DEREGISTER state. In this state, it issues the OMP.request primitive indicating the REGISTER_REQ message with the de-registration flag to the OMP Multiplexer and issues the MA_CONTROL.indication primitive to inform the client of de-registration. Then, it transits to the WAIT state.

- Expiration of omp_timer

At the expiration of omp_timer, the Discovery Process transits to the LOCAL DEREGISTER state. The sequential behavior is same as de-registration from ONU case.

64.3.3.3 Discovery Message Handshake

The OLT starts the discovery procedure by sending the GATE message with the discovery flag. This message is called as Discovery GATE and will be frequently sent to discover additional unregistered ONUs. The Discovery GATE message contains only one grant which may have long length to register multiple ONUs. Additionally, this message contains the AGC settling time and the CDR lock time. After sending the Discovery GATE message, the OLT opens the discovery window based on the assigned grant. When an unregistered ONU receives the Discovery GATE message, it invokes a timer at the beginning of grant. This timer means the random delay which is used to avoid the collision of registrations from multiple ONUs. After this timer expires, the ONU sends the REGISTER_REQUEST message. This message contains the pending grants. If the OLT receives the REGISTER_REQUEST message without collision during the discovery window, it selects one of unassigned LLIDs, assigns the selected LLID to the ONU which sent the REGISTER_REQUEST message, and sends the REGISTER message. This message contains the Assigned port, the AGC settling time, the CDR lock time and the echo of pending grants. The selected LLID is included in the Assigned port field. Additionally, the OLT sends the GATE message without the discovery flag to solicit the acknowledge message from the ONU. This message is called as Normal GATE, and the LLID is indicated in the MAC preamble. If the ONU receives the REGISTER message, it recognizes that the logical link has been correctly established. The LLID indicated in the Assigned port field in the REGISTER message is assigned to this logical link. After that, if the ONU receives the Normal GATE message, it sends the REGISTER_ACK message using the specified grant. The LLID is indicated in the MAC preamble.

When the OLT receives the REGISTER_ACK message, it completes the discovery procedure and begins to send the Normal GATE messages to solicit the data transmission.

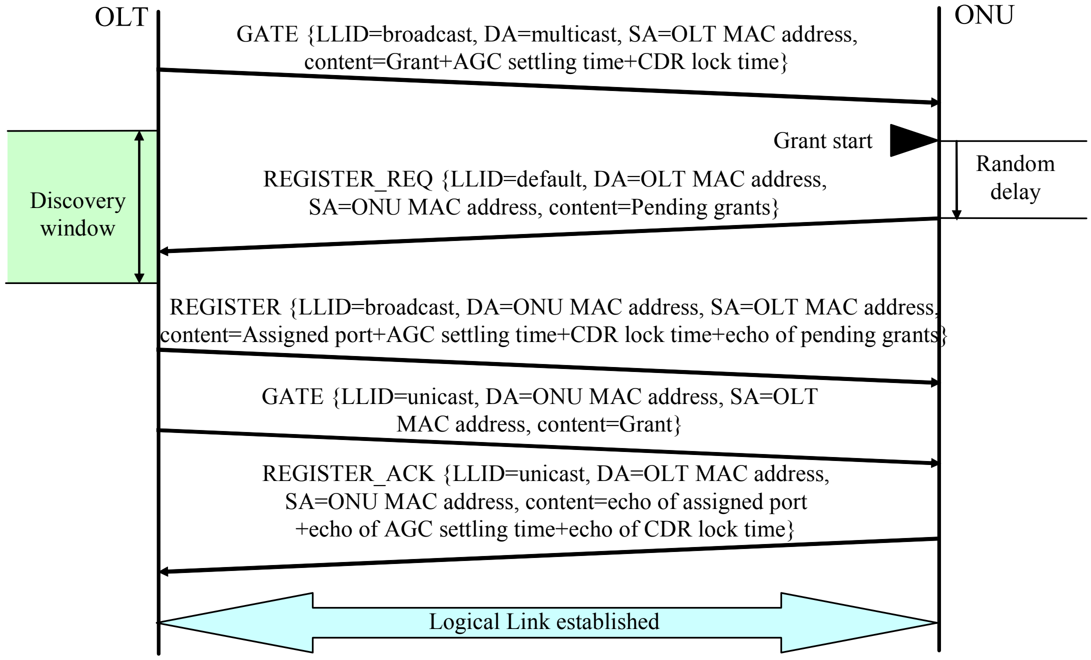


Figure 64–13—Discovery handshake message exchange

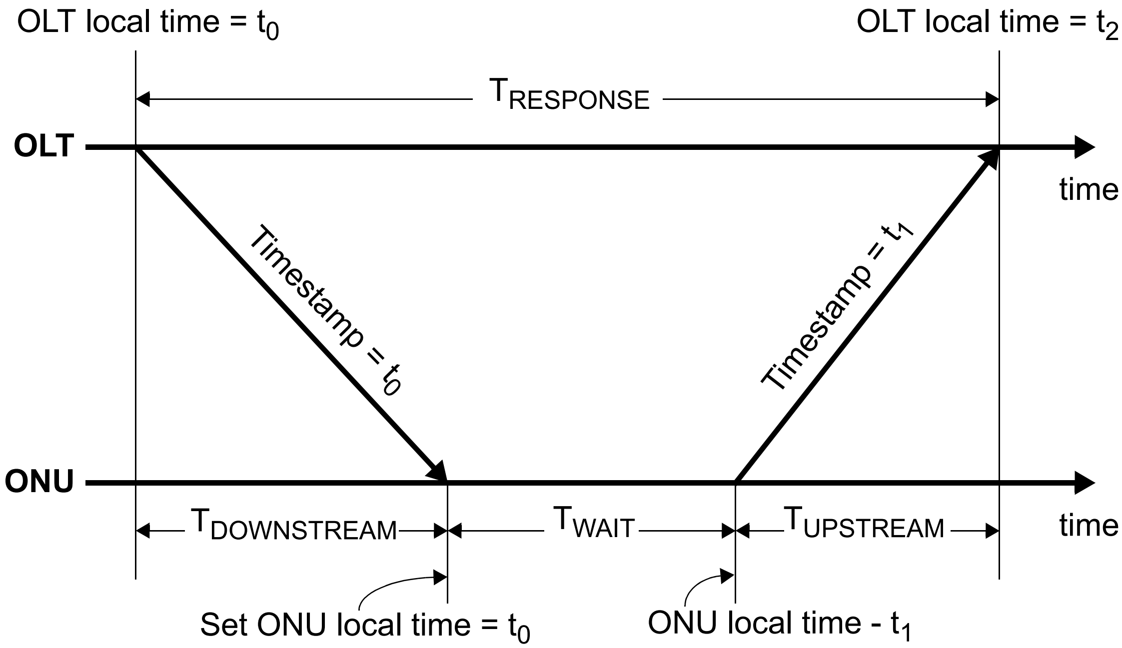
64.3.3.4 Ranging and Timing Process

The OLT has a 32 bits counter. This counter is incremented every 16 bit transmission. When the OLT transmits MPCPDUs, it maps the counter value in the timestamp field.

The ONU also has a 32 bit counter. This counter is also incremented every 16 bit transmission. Additionally, this counter is used to set the value of timestamp field whenever the ONU receives MPCPDUs. When the ONU transmits MPCPDUs, it maps the counter value minus the processing delay in the timestamp field.

The OLT measures the round trip time of ONU whenever it receives MPCPDUs. The RTT is equal to the difference between the counter value and the value in the timestamp field. Since the ONU sets the counter value minus the processing delay in the timestamp filed, the processing delay is absorbed in the RTT at the OLT.

The calculated RTT is notified to the client via the MA_CONTROL.indication primitive. The client can use this RTT for the ranging process.



$T_{DOWNSTREAM}$ = downstream propagation delay
$T_{UPSTREAM}$ = upstream propagation delay
T_{WAIT} = wait time at ONU ($T_{WAIT} = T_1 - T_0$)
$T_{RESPONSE}$ = response time at OLT ($T_{RESPONSE} = T_2 - T_0$)

$$RTT = T_{DOWNSTREAM} + T_{UPSTREAM} = T_{RESPONSE} - T_{WAIT} = (t_2 - t_0) - (t_1 - t_0) = t_2 - t_1$$

Figure 64–14—Round trip time calculation

64.3.3.5 MPCP Report Process

(1) OLT

At the OLT, the WAIT state is the initial state of the Report Process. In this state, the Report Process waits for the OMP.indication primitive from the OMP Parser. The OMP.indication primitive contains the contents of REPORT message received from the ONU. When the Report Process receives the OMP.indication primitive, it transits to the RECEIVE REPORT state. In this state, it issues the MA_CONTROL.indication primitive to inform the client of reports information and the calculated RTT. Then, it transits to the WAIT state.

(2) ONU

- Normal case

At the ONU, the WAIT state is the initial state of the Report Process. In this state, the Report Process waits for the MA_CONTROL.request primitive from the client. The MA_CONTROL.request primitive contains the contents of REPORT message to be sent. When the Report Process receives the MA_CONTROL.request primitive, it transits to the SEND REPORT state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the REPORT message and starts the periodic_timer. Then, it transits to the WAIT state.

- Expiration of periodic_timer

The Report Process uses the periodic_timer to send the REPORT messages at certain intervals. The Report Process starts this timer whenever it issues the OMP.request primitive indicating the REPORT message. At the expiration of periodic_timer in the WAIT state, the Report Process transits to the PERIODIC TRANSMISSION state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the REPORT message that contains no queue report and starts the periodic_timer. Then, it transits to the WAIT state.

- Completion of Discovery procedure

At the completion of Discovery procedure, the Report process transits to the PERIODIC TRANSMISSION state. In this state, it issues the OMP.request primitive to the OMP Multiplexer to send the REPORT message that contains no queue report and starts the periodic_timer. Then, it transits to the WAIT state.

64.3.4 Compatibility considerations

64.3.4.1 PAUSE operation

Even though MPCP is compatible with flow control, flow control may not be efficient in the case of large propagation delay.

64.3.4.2 Shared LAN Emulation

By combining P2PE, suitable filtering rules at the ONU, and suitable forwarding/reflecting rules at the OLT, it is possible to emulate an efficient shared LAN (SE). This is performed in a layer above the MAC, and thus is introduced here for informational purposes only.

At the OLT, the rules for setting the mode and LLID parameters are as follows:

a) External Broadcast frame: (mode = 1, Broadcast_LLID)
b) External Unicast frame to known LLIDn: (mode = 0, LLIDn)
c) External Unicast frame to unknown LLID: (mode = 1, Broadcast_LLID)
d) Internal Unicast frame from LLIDn to LLIDm: (mode = 0, LLIDm)
e) Internal Broadcast frame from LLIDn: (mode = 1, LLIDn)
f) Internal Unknown frame from LLIDn: (mode = 1, LLIDn)

At the ONU, the rules for setting the mode and LLID parameters are as follows:

g) Upstream Frames: Send frame with the corresponding LLID and mode-bit set to zero

At the ONU, the rules for filtering incoming frames are as follows:

h) If mode-bit is zero and the LLID is this ONU- Accept frame
i) If mode-bit is one and the LLID is not this ONU, or the LLID is the broadcast LLID - Accept frame
j) All other frames are discarded

Specific behavior of the filtering layer at the RS is specified in #CrossRef# 65.1.3.2.2.

64.3.4.3 Multicast and single copy bradcast support

In the downstream direction, the PON is a broadcast medium. In order to make use of this capability for forwarding broadcast frames from the OLT to multiple recepients without multiple duplication for each ONU, the multicast and SCB support is introduced.
Each unicast MAC has a corresponding multicast MAC for broadcasting traffic to all ONUs except the one associated with that MAC. In addition one more MAC at the OLT is marked as the SCB MAC. This increases the number of MACs within the OLT to 2N+1. The SCB MAC handles all downstream broadcast traffic, but is never used in the upstream direction for client traffic. When connecting the SCB MAC to an 802.1D bridge port it is possible that loops may be formed due to the broadcast nature. Thus it is recommended that this MAC shall not be connected to an 802.1D bridge port.

Filtering and marking of frames for support of SCB is defined in #CrossRef# subclause 65.1.2.4.2.

64.3.4.4 Delay requirements

The MPCP protocol relies on strict timing based on distribution of timestamps. A compliant implementation shall guarantee a constant delay through the MAC and PHY in order to maintain the correctness of the timestamping mechanism. The actual delay is implementation dependant however a complying implementation shall maintain a delay variation of no more than 32 bit times through the implemented Ethernet stack.

The OLT shall not grant nearer than 1024 time_quantas into the future. The ONU shall process all messages in less than this period. time_quanta are defined as 16 bit times. Bit times are defined as a function of the PMD rate. #CrossRef# Clause 58 defines the PMD for a P2MP topology operating at 1000Mbps.

64.3.5 Shared Variables

localTime

This variable holds the value of the local counter used to control OMP operation. This variable is advanced by a timer at 62.5MHz, and counts in time_quanta. At the OLT the counter shall track the tranmit clock, while at the ONU the counter shall track the receive clock. It is periodically reset by the OMP functional block on notification of the existence of a more accurate timebase.
The unit time_quanta is used by all mechanisms synchronized to the advancement of the local_time variable. Variable used to store counters and time intervals are defined using time_quanta.
Changing the value of this variable while running using Layer Management is highly undesirable and is unspecified.

TYPE:	32 bit unsigned
DEFAULT VALUE:	00-00-00-00

Master

This variable is used to signal whether the OMP instance is dominant in the network it resides in. It is set by Layer Management based on the behavior of the node. Typically when Master is true the node is an OLT on the specified interface.
Changing the value of this variable while running is unspecified.

TYPE:	boolean
DEFAULT VALUE:	true for OLT false for ONU

64.3.6 Shared Functions

a < b

This function is used to compare two time values. Return value is true when b is larger than a allowing for wrap around of a and b.
The comparison is made by subtracting a from b and testing the MSB. When MSB(a-b) = 1 the value true is returned, else false is returned.

64.3.7 OMP Parser/Multiplexer

64.3.7.1 Timers

omp_timer

This timer is used to measure the arrival rate of OMP frames in the link. Failure to receive frames is considered a fatal fault and requires a hard reset to the OMP functional block. The timeout value is 03-B9-AC-A0 (1 second).

64.3.8 Discovery Processing

Discovery is the process whereby newly connected or off-line ONUs are provided access to the PON. The process is driven by the OLT, which periodically makes available Discovery Time Windows during which off-line ONU's are given the oppurtunity to make themselves known to the OLT. The periodicity of these windows is unspecified and left up to the implementer. The OLT signifies that a discovery period is occuring by broadcasting a discovery gate message which includes the starting time and length of the discovery window. Off-line ONUs, upon receiveing this message, wait for the period to begin and then transmit a Register_Req message to the OLT. Discovery windows are unique in that they are the only times where multiple ONUs can access the PON simultaneously, and tranmission overlap can occur. In order to reduce transmission overlaps a contention algorithm is used by all ONUs. Measures are taken to reduce the probability for overlaps by artificially simulating a random distribution of distances from the OLT. Each ONU shall wait a random amount of time before transmitting the Register_Req message. This random time shall be shorter than the length of the discovery time window. It should be noted that multiple valid Register_Req messages can be received by the OLT during a single discovery time period. Included in the Register_Req message is the ONU's MAC address. Upon receipt of a valid Register_Req message, the OLT registers the ONU, allocating and assigning new port identities (LLIDs), and bonding corresponding MACs to the LLIDs.

The next step in the process is for the OLT to transmit a Register message to the newly discovered ONU which contains the ONU's LLID, and the OLT's required syncronization time. Also, the OLT echoes the pending grants. The OLT now has enough information to schedule the ONU for access to the PON and transmits a standard GATE message allowing the ONU to transmit a Register_Ack. Upon receipt of the Register_Ack, the discovery process for that ONU is complete, the ONU is registered and normal message traffic can begin. It is the responsibility of Layer Management to perform the MAC bonding, and start transmission from/to the newly registered ONU.

There may exist situations when the OLT requires that an ONU go through the discovery sequence again and reregister. Similarly, there may be situations where an ONU needs to inform the OLT of its desire to deregister. The ONU can then reregister by going through the discovery sequence. For the OLT, the REGISTER message contains two bits, Force registration and Deallocate (deregister), that if either is set will force the receiving ONU into reregistering. For the ONU,the REGISTER_REQ message contains the Deregister bit that signifies to the OLT that this ONU should be deregistered.

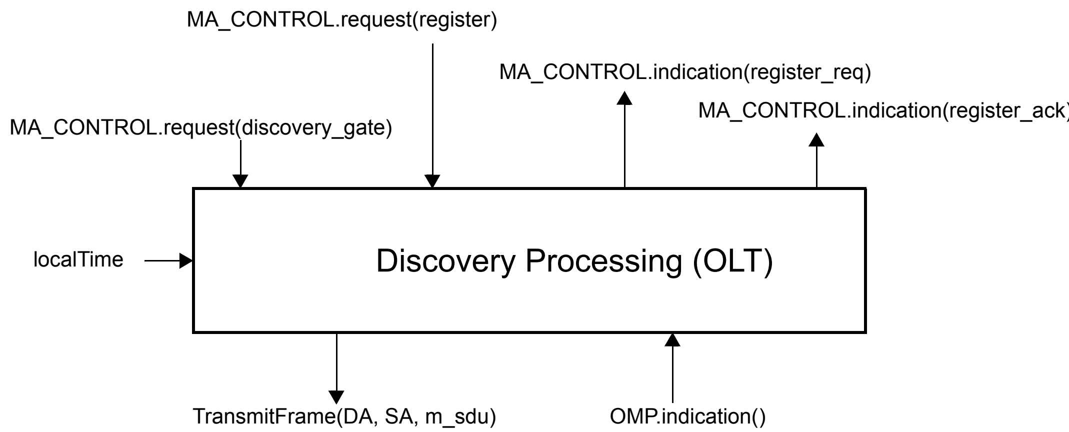


Figure 64–15—Discovery Processing Service Interfaces (OLT)

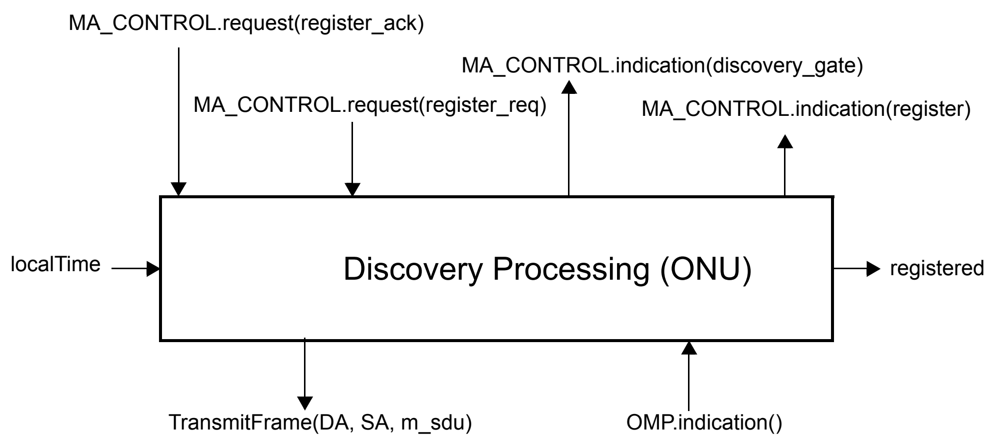


Figure 64–16—Discovery Processing Service Interfaces (ONU)

64.3.8.1 Constants

broadcast_ID

This constant holds the port identifier for the global broadcast MAC instance. Its value follows the convention of #CrossRef# Clause 65.

TYPE: 16 bit unsigned

DEFAULT VALUE: FF-FF

laser_on_time

This constant holds the time required to initiate the laser. It counts in time_quanta units, the time from the laserControl signal assertion, to the point where transmission output is stable and decodable.

TYPE: 32 bit unsigned

DEFAULT VALUE: 00-00-00-25 (600 nano seconds) laser_off_time

This constant holds the time required to terminate the laser. It counts in time_quanta units, the time from the laserControl signal deassertion, to the point where transmission output is undetectable.

TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-25 (600 nano seconds)

64.3.8.2 Variables

BEGIN

This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.

TYPE: boolean
DEFAULT VALUE: true

registered

This variable holds the current value result of the Discovery Process. It is set to true once the discovery process is complete, and registration is acknowledged.

TYPE: boolean
DEFAULT VALUE: false for ONU
true for OLT

insideDiscoveryWindow

This variable holds the current status of the discovery window. It is set to true once the discovery window is open, and false otherwise.

TYPE: boolean
DEFAULT VALUE: false

64.3.8.3 Functions

is_unicast(MACAddress)

This function is used to check whether the 48 bit MAC address represents a unicast MAC address. The function returns the value true when MAC Adress is unicast according to the definitions in Clause 3.2.3, and false otherwise.

integer max(A, B)

This function is used to compare the values of A against B, and return the largest value. If A>B than the function returns A, otherwise the function returns B.

integer random(r)

This function is used to compute a random integer number uniformly distributed between 0 and r. The rendomly generated number is then returned by the function.

64.3.8.4 Timers

wait_for_window_timer

This timer is used to wait for the event signalling the start of the discovery window.
VALUE: the timer value is set dynamically based on the parameters passed from the client.

discovery_window_size_timer

This timer is used to wait for the event signalling the end of the discovery window.
VALUE: the timer value is set dynamically based on the parameters passed from the client.

ONU_timer

This timer is used to measure the time since the arrival of the last message in the registration process from the ONU.

Failure of a REGISTER_ACK message to arrive by the time the timer expires is a fatal error in the discovery process, and causes registration to fail for the specified ONU, who may then retry to register.

VALUE: 00-09-89-68 (10 msecs).

random_delay_timer

This timer is used to measure a random delay inside the discovery window. The purpose of the delay is to apriori reduce the probability of transmission overlap during the registration process, and thus lowering the expectancy of registration time in the PON.

VALUE: A random value less than the net discovery window size less the REGISTER_REQ MPCPDU frame size less the idle period and laser turn on and off delays. The timer value is set dynamically based on the parameters passed from the client.

IDLE_timer

This timer is used to wait for the event signalling the end of the period till PDUs are allowed transmission inside the grant window. This period, where only IDLE symbol-pairs are transmitted is used to allow clock synchronization acquisition for the receiving entity.

VALUE: the timer is set according to the OLT capabilities broadcast and may vary.

grant_window_timer

This timer is used to wait the entire period of time where transmssion is bursting in the uplink during a registration attempt. The transmission during registration attempt is comprised of the following parts: preamble, REGISTER_REQ frame, closing sequence (/T/R/R/), and IFG for a total of 87 bytes (696 ns)

VALUE: 00-00-00-2C (696 nano seconds, equivalent of 87 bytes).

64.3.8.5 Messages

Editor's Note (to be removed prior to publication): Comment 265 on D1.3 conflicts with the definition of MA_CONTROL.request(DA, register_req, ...) and is irreconsilable. Further comments are solicited.

Collection of all messages to a single location in text still required per commetn 174 on D1.3.

OMP.indications to be changed to function-activation, OMP.request to be changed to TransmitFrame. Further comments are solicited.

MA_CONTROL.request(DA, register_req, register)

The service primitive used by a client at the ONU to request the Discovery Process to perform a registration.

register: Boolean operand describing whether the station is attempting to register (true) or deregister (false).

MA_CONTROL.indication(register_req, status, flags, pending_grants, RTT)

The service indication issued by the Discovery Process at the OLT to notify the client and Layer Management that the registration process is in progress.

The status parameter holds the values incoming, or retry.

The flags parameters holds the contents of the flags field in the REGISTER_REQ message.

The pending_grants parameters holds the contents of the pending_grants field in the REGISTER_REQ message.

The measured round trip time to/from the ONU is returned in the parameter RTT. RTT is stated in time_quanta units. This parameter holds a valid value only when the invoking Discovery Process is in the OLT (i.e. Master = true).

MA_CONTROL.request(DA, register, start_time, grant_length, length)

The service primitive used at the OLT and at the ONU by a peer or client to request the Discovery Process to acknowledge the existence of a discovery window.

The DA parameter is the MAC address of the device requested to register in this window. The device may be recognized by its unicast address, or multiple devices may be requested when using the MAC Control well known multicast address.

The start_time parameter, holds the time (relative to the local_time counter), at which the discovery window will become active.

The grant_length parameter indicates the length of the discovery window as indicated by the accompanying GATE. grant_length shall be at lease twice the size of a REGISTER_REQ MPCPDU with overheads, with additional space reserved for each ONU expected to register simultaneously.

The length parameter indicates the length of the allocated discovery window in time_quanta. length shall be at least grant_length with additional space reserved for the expected RTT of the deployed network.

Editor's Note*: Need to remove reference to Master from next paragraph*

When Master = true (i.e. OLT mode), and the function is invoked, a grant is issued with the relevant start_time and grant_length parameters, addressed to DA. For a DTE where Master = false (i.e. ONU mode), this function may not be called by the MAC client, and rather it is invoked by the Gate Processing peer entity to signal the arrival of a grant used for discovery.

MA_CONTROL.request(DA, register_ack, ID, register_status)

The service primitive used by the client at the OLT to initiate acceptance of an ONU.

The parameter ID holds the LLID assigned by the client.

The parameter register_status holds the values accept, or deny.

MA_CONTROL.indication(register_ack, SA, ID, status, RTT)

The service indication issued by the Discovery Process at the OLT or at the ONU to notify the client and Layer Management that the registration process has completed.

The MAC address of the recipricating MAC (ONU address at the OLT, and OLT address at the ONU) is passed in the parameter SA. The LLID allocated to the ONU is passed in the parameter ID.

The parameter status holds the possible values: accepted, denied, reset, deregistered.

The measured round trip time to/from the ONU is returned in the parameter RTT. RTT is stated in time_quanta units. This parameter holds a valid value only when the invoking Discovery Process is in the OLT (i.e. Master = true).

MA_CONTROL.request()

The service primitive used by a client to request a Gate Processing functional block function with the specified request_operands.

64.3.8.6 State Diagram

Editor's Note: To be removed prior to publication*. Comment 336 on Draft 1.2 has asked for multiple outstanding discovery windows. Editor is yet to find elegant solution for supporting this. Commetns are welcome. Some state diagrams rely on a variable named 'state' that is no longer in use.*

Instantiation of state machines as described in Figure 64–17, Figure 64–18, and Figure 64–20 are performed only at the MAC attached to the broadcast LLID. Instantiation of state machines as described in Figure 64–19 and Figure 64–21 are perfomed for every MAC.

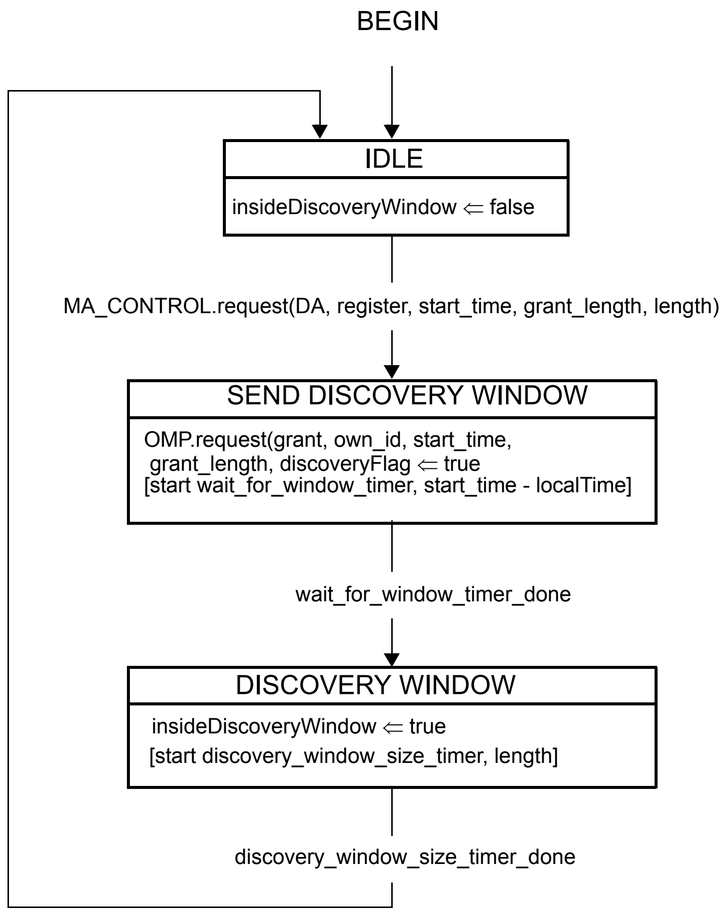


Figure 64–17—Discovery Processing OLT Window Setup State Diagram

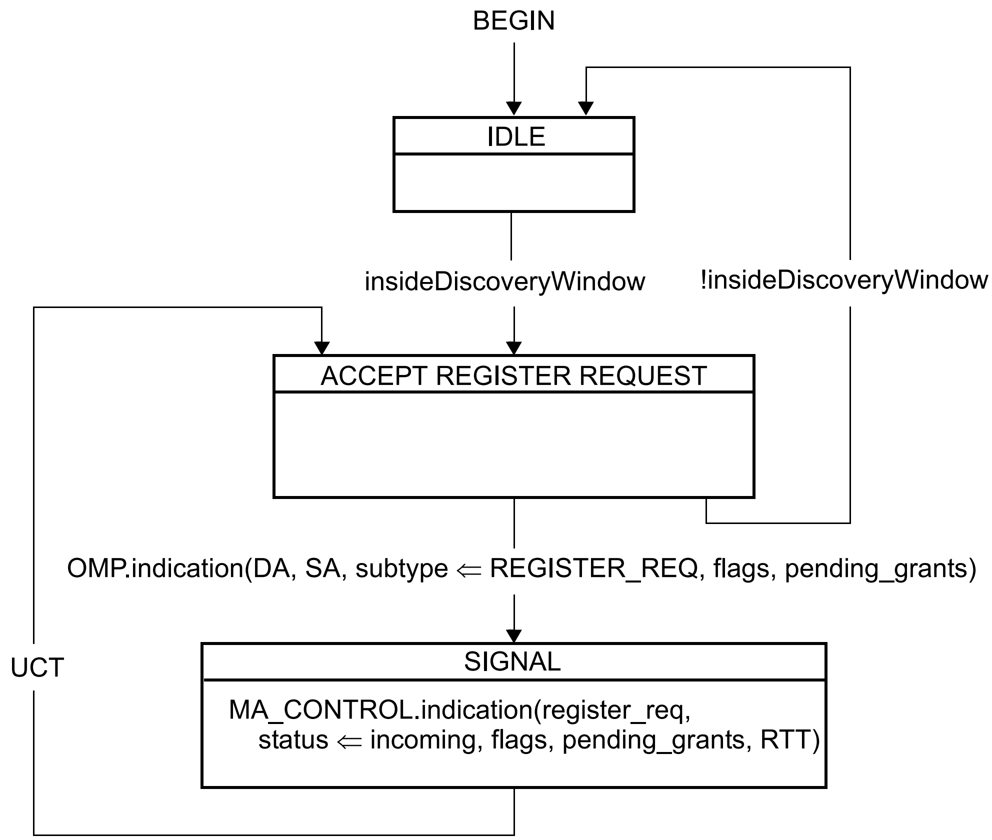


Figure 64–18—Discovery Processing OLT Process Requests State Diagram

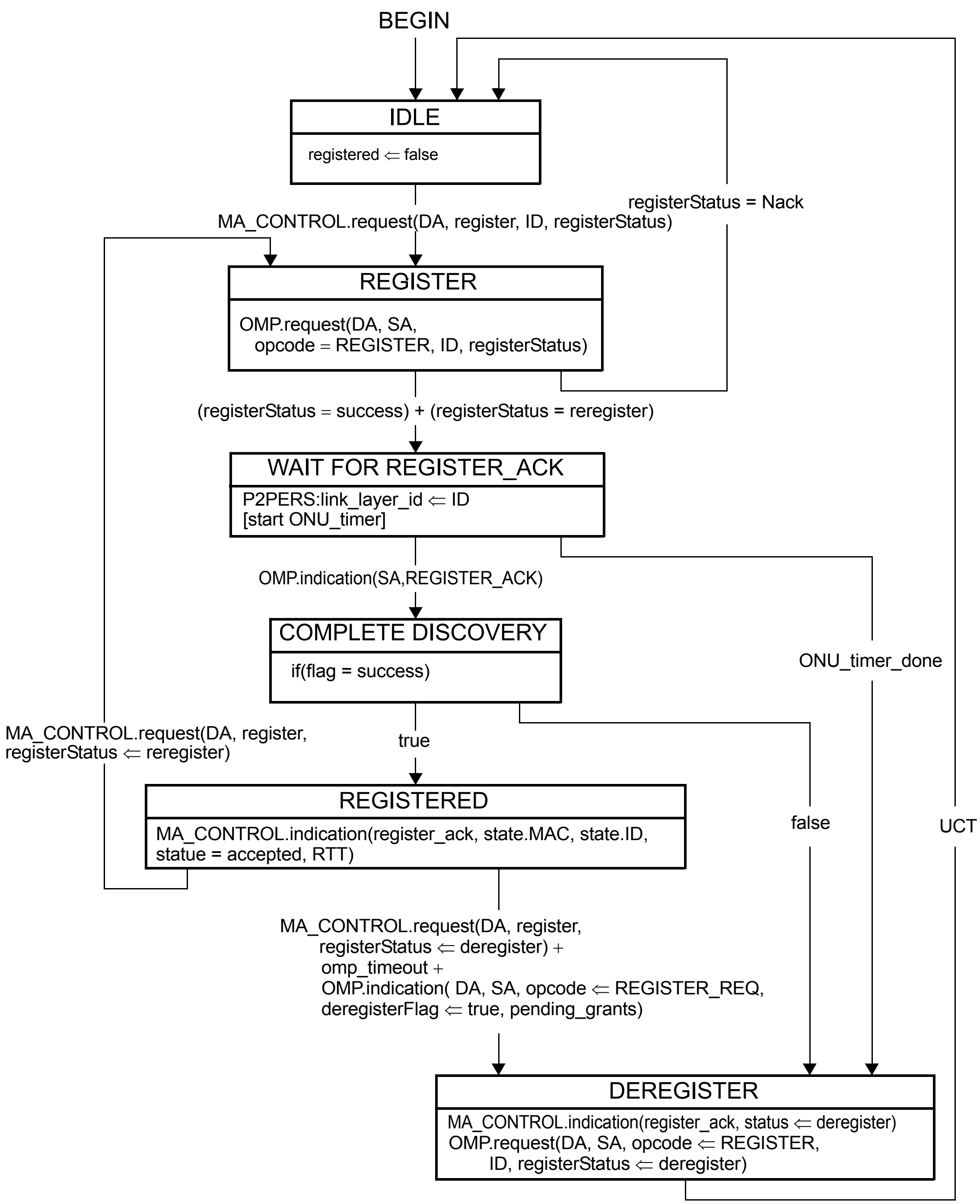


Figure 64–19—Discovery Processing OLT Final Registration State Diagram

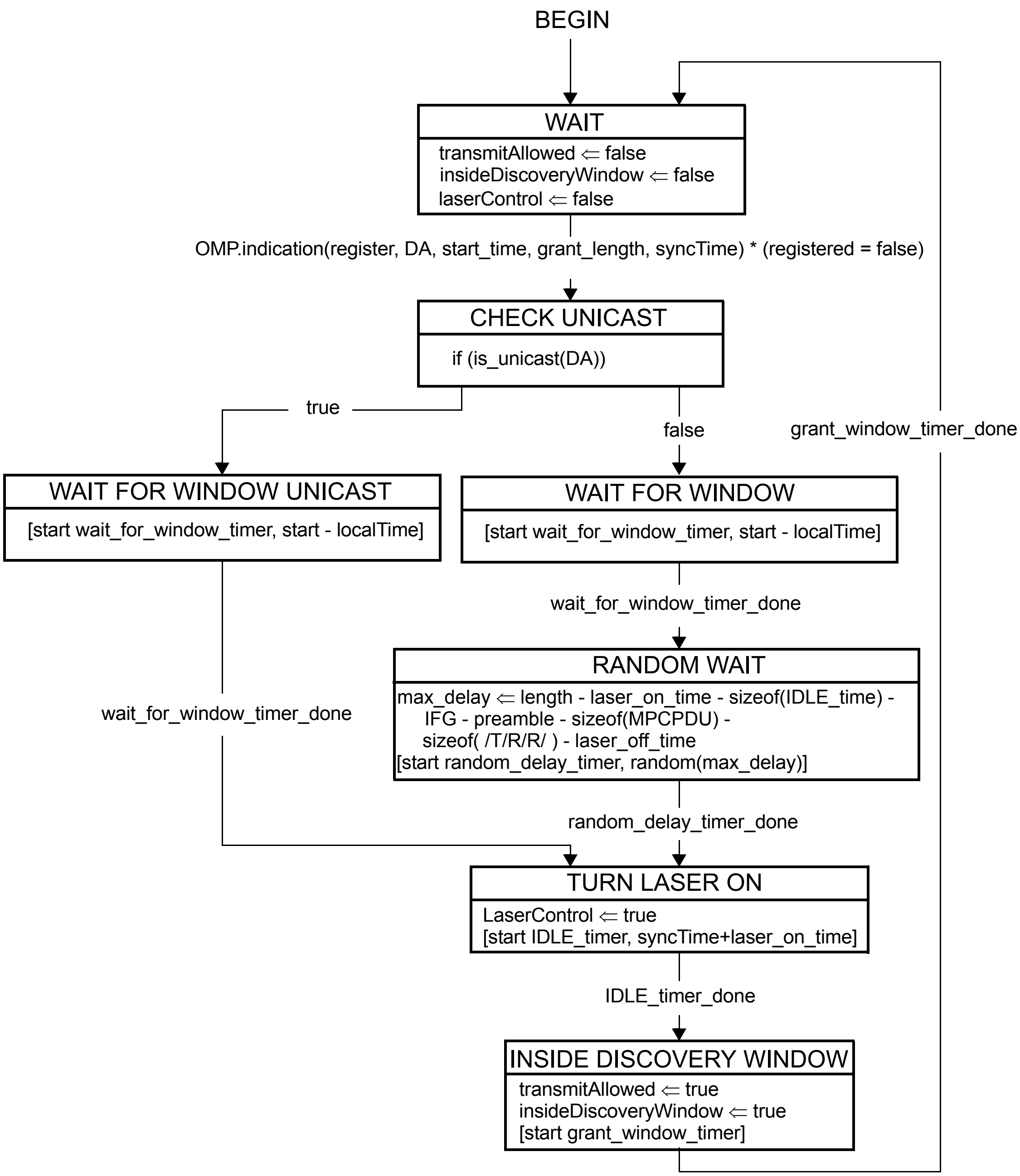


Figure 64–20—Discovery Processing ONU Window Setup State Diagram

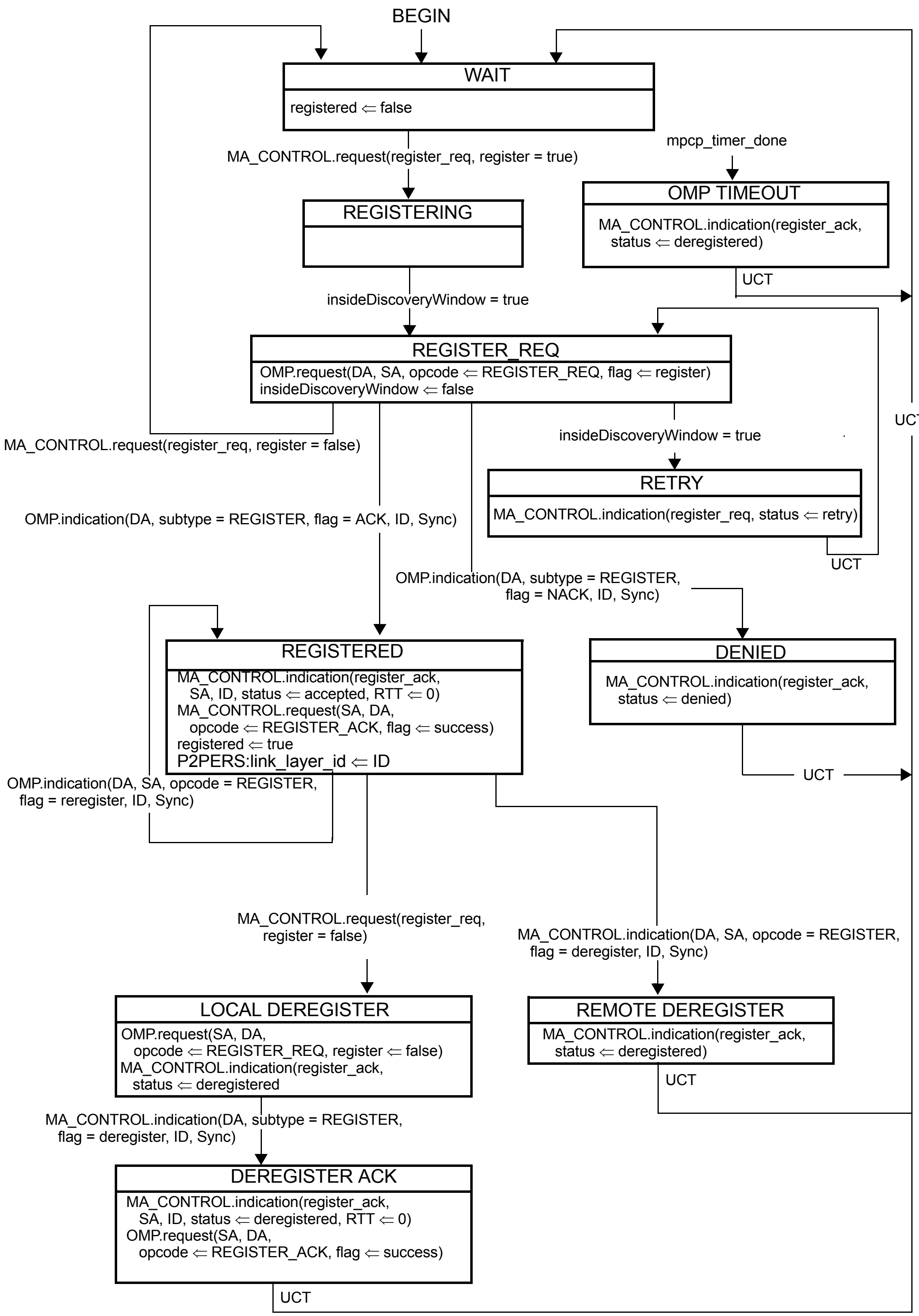


Figure 64–21—Discovery Processing ONU Registration State Diagram

64.3.9 Report Processing

The Report Processing functional block has the responsibility of dealing with queue report generation and termination in the network. Reports are generated by higher layers and passed to the MAC Control sublayer by the MAC Control clients. Typically status reports are used to signal bandwidth needs. Queue reports shall be specified in 2-byte multiples.

Queue reports shall be generated periodically, even when no request for bandwidth is being made. This keeps a watchdog timer in the OLT from expiring and deregistering the ONU. For proper operation of this mechanism the OLT shall grant the ONU periodically.

The Report Processing functional block, and its MPCP protocol elements are designed for use in conjunction with an 802.1P capable bridge.

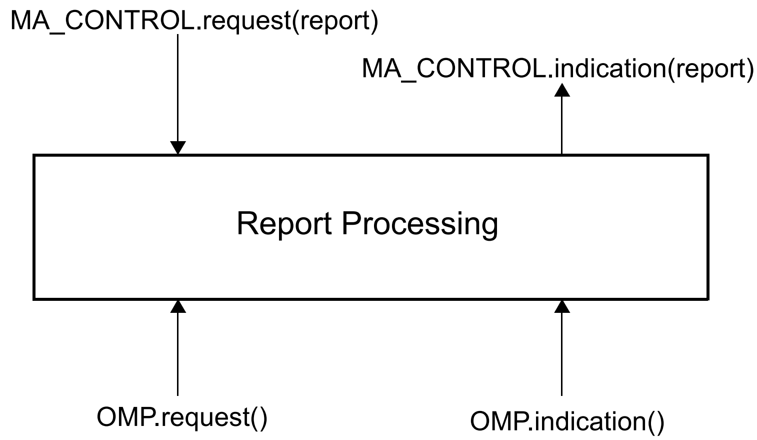


Figure 64–22—Report Processing Service Interfaces

64.3.9.1 Constants

No constants are defined for the Report Processing functional block.

64.3.9.2 Variables

BEGIN
This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.
TYPE: boolean
DEFAULT VALUE: true

64.3.9.3 Functions

No functions are defined for the Report Processing functional block

64.3.9.4 Timers

report_periodic_timer
This timer is used to wait for the event signalling the requirement to generate a REPORT MPCPDU. The ONU is required to generate REPORT MPCPDU with a periodicity of less than timeout_value.
VALUE: 00-2F-AF-08 (50 milliseconds)

64.3.9.5 Messages

MA_CONTROL.request(report, n, report_list)

The service primitive used by a client to request the Report Process at the ONU to transmit a queue status report. This primitive may be called multiple times, in order to reflect the time-varing aspect of the network. The list of queue status reports of length n issued by ONU are passed in the parameter report_list. A queue status report has two parameters, valid and status. The parameter valid, is a boolean array with length of 8, ‘0’ or false indicates that the corresponding queue is empty while ‘1’ or true indicates that the queue has some data. The parameter status is a short integer array of length 8. For each valid entry in the array status, the same indexed entry in the array valid is set to true. The index of the array is meant to reflect the same numbered priority queue in the 802.1P numenclature.

MA_CONTROL.indication(report, RTT, n, report_list)

The service indication issued by the Report Process at the OLT to notify the MAC Control client and higher layers the queue status of the MPCP link partner.

This primitive may be called multiple times, in order to reflect the time-varing aspect of the network. The list of queue status reports of length n issued by ONU are passed in the parameter report_list. A queue status report has two members, valid and status. The parameter valid, is a boolean array with length of 8, ‘0’ or false indicates that the corresponding queue is empty while ‘1’ or true indicates that the queue has some data. The parameter status is an integer array of length 8. For each valid entry in the array status, the same indexed entry in the array valid is set to true. The index of the array is meant to reflect the same numbered priority queue in the 802.1P numenclature.

The parameter RTT holds the updated round trip time value as calculated following the REPORT message reception.

64.3.9.6 State Diagram

Editor’s note (to be removed prior to publication): opcode dependant OMP watchdog should be moved here for OLT.

Instantiation of state machines as described is perfomed for MACs attached to unicast LLID only.

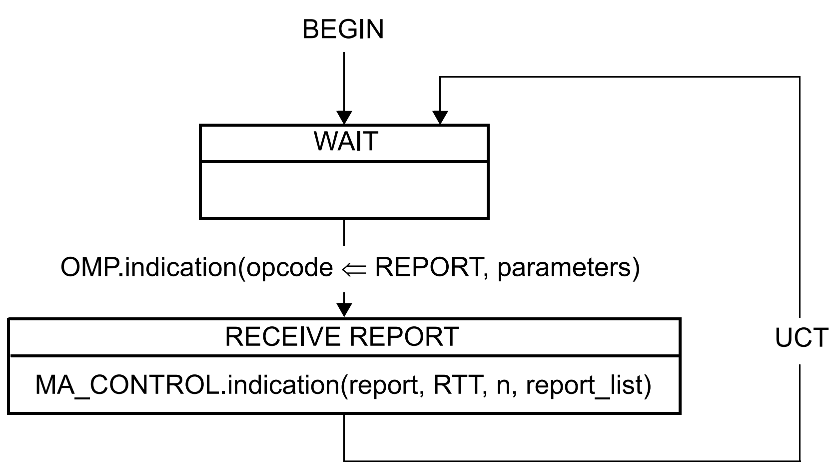


Figure 64–23—Report Processing State Diagram at OLT

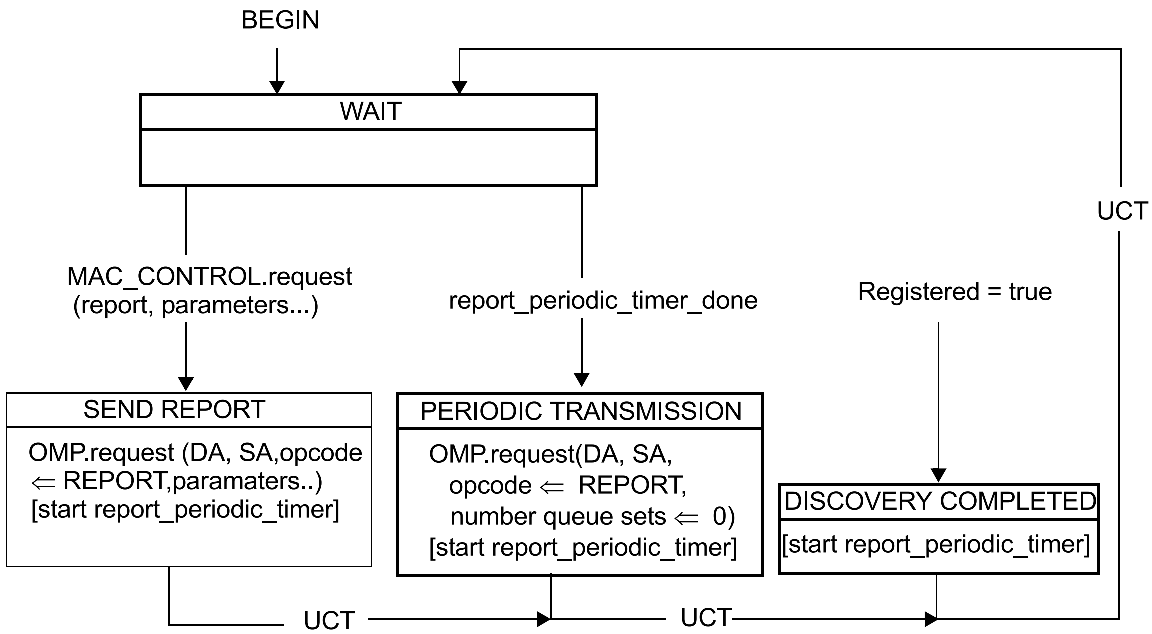


Figure 64–24—Report Processing State Diagram at ONU

64.3.10 Gate Processing

A key concept pervasive in Optical Multi-Point is the ability to arbitrate a single transmitter out of a plurality of DTEs. Once arbitration is achieved, transmission latching ensures that no frames are forwarded to the MAC when the DTE is not in the forwarding state.

The transmitting window of an ONU is indicated in GATE message where start time and length is specified. At start time ONU may turn laser on for transmitting. When a time indicated by length is elapsed since the start time, the laser shall be off again. The windows of different ONUs may overlap during the period where one laser is turning off and the next one is turning on.

Multiple outstanding grants may bew issued to each ONU. The OLT shall not issue more than the maximal supported maximal outstanding grants as advertised by the ONU during registration (see Pending grants in 64.4.4).

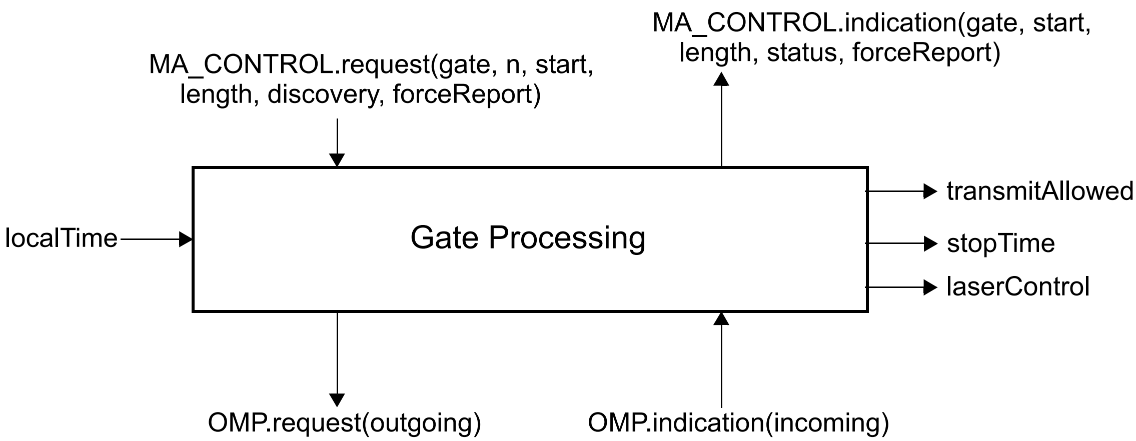


Figure 64–25—Gate Processing Service Interface

64.3.10.1 Constants

laser_on_time

This constant holds the time required to initiate the laser. It counts in time_quanta units, the time from the laserControl signal assertion, to the point where transmission output is stable and decodable.

TYPE:	32 bit unsigned
DEFAULT VALUE:	00-00-00-25 (600 nano seconds)

laser_off_time

This constant holds the time required to terminate the laser. It counts in time_quanta units, the time from the laserControl signal deassertion, to the point where transmission output is undetectable.

TYPE:	32 bit unsigned
DEFAULT VALUE:	00-00-00-25 (600 nano seconds)

64.3.10.2 Variables

BEGIN

This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.

TYPE:	boolean
DEFAULT VALUE:	true

currentGrant

This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed.
The state is a structure field composed of multiple subfields.

TYPE:	structure {	
	DA	48 bit unsigned, a.k.a MAC address type
	start	32 bit unsigned
	length	16 bit unsigned
	force_report	boolean}
DEFAULT VALUE:	{FF-FF-FF-FF-FF-FF, 00-00-00-00, 00-00, false}	

grantList

This variable is used for storage of the list of pending grants. It is dynamically set by the Gate Processing functional block and is not exposed. Each time a grant is received it is added to the list.

The list elements are structure fields composed of multiple subfields.

The list is indexed by the start subfield in each element for quick searches.

TYPE: list of elements having the structure define in currentGrant
DEFAULT VALUE: empty

laserControl

This variable is used to control the transmit path. It is set to true when the transmit path is enabled, and is set to false when the transmit path is being shut down. laserControl is always on for the OLT. For the ONU, laserControl changes its value according to the state of the Gate Processing functional block.

TYPE: boolean
DEFAULT VALUE: false for ONU
true for OLT

transmitAllowedtransmitAllowed

This variable is used to control PDU forwarding in the transmit path. It is set to true when the transmit path is enabled, and is set to false when the transmit path is being shut down. transmitAllowed is always true for the OLT, and changes its value according to the state of the Gate Processing functional block.

TYPE: boolean
DEFAULT VALUE: false for ONU
true for OLT

time

This variable is used for temporary storage of a normalized time value. It holds the expected start time of an event normalized for elapsed time.

TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-00

effectiveLength

This variable is used for temporary storage of a normalized net time value. It holds the net effective length of a grant normalized for elapsed time, and compensated for the periods required to turn the laser on and off, and waiting for receiver lock.

TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-00

stopTime

This variable holds the value of the local counter at the end of the nearest grant.

TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-00

IDLETime

This variable holds the time required to stabilize the receiver at the OLT. It counts in time_quanta units from the point where transmission output is stable to the point where it is decodable. During the IDLE_time only IDLE patterns can be transmitted.

This value is set following registration, as it is broadcast by the OLT.

TYPE: 32 bit unsigned
DEFAULT VALUE: 00-00-00-10 (256 nano seconds)

64.3.10.3 Functions

empty(list)

This function is used to check wheter list is an empty list. When there are no elements queued in list the fuction returns true as a result. Otherwise a value of false is returned.

insert_sorted_list(list, element)

This function is used to queue the element structure element inside the list list. The queueing order is sorted.

remove_list(list, element)

This function is used to dequeue the element structure element from the list list.

max(A, B)

This function is used to compare the values of A against B, and return the largest value. If A>B than the function returns A, otherwise the function returns B.

min(A, B)

This function is used to compare the values of A against B, and return the smallest value. If A<B than the function returns A, otherwise the function returns B.

64.3.10.4 Timers

grant_start_timer

This timer is used to wait for the event signalling the start of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant start time.

IDLE_timer

This timer is used to wait for the event signalling the end of the period where no PDUs are allowed transmission inside the grant window. This period, where only IDLE symbol-pairs are transmitted is used to allow clock synchronization acquisition for the receiving entity.
VALUE: This timer is set according to the value in the IDLE_time variable

grant_window_timer

This timer is used to wait for the event signalling the end of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant length.

gate_periodic_timer

This timer is used to wait for the event signalling the requirement to generate a GATE MPCPDU. The OLT is required to generate GATE MPCPDU with a periodicity of at least timeout_value.
VALUE: 00-2F-AF-08 (50 milliseconds)

64.3.10.5 Messages

MA_CONTROL.request(gate, n, start[4], length[4], discovery, force_report[4])

The service primitive used by a client at the OLT to request the Gate Process to acknowledge a pending grant. This primitive may be called multiple times in order to create multiple consecutive, or non consecutive pending grants.
The parameter n holds the number of valid entries in the two arrays start and length. The last valid entry being n-1.
The boolean flag discovery, signals that the grants are intended for use by the discovery process.
The boolean flags force_report[4] hold true for the grant where it is requested that the ONU generate a report message.

MA_CONTROL.indication(gate, start, length, status, force_report)

This service indication issued by the Gate Process at the ONU to notify the MAC Control client and higher layers that a grant has been issued and is pending.

This indication is issued multiple times when a single GATE message arrives with multiple entries. It is also generated at the start and end of each grant as it becomes active.

The status parameter receives the value arrive on grant reception, active when a grant becomes active, and deactive at the end of a grant.

The force_report parameter holds the value true when the OLT expects the ONU to generate a REPORT at the next tranmission opportunity folowing this indication. It is the responsibility of the MAC Control Client to actually generate the REPORT in a timely fashion.

OMP.request()

The service primitive used by a client to request an OMP functional block function with the specified request_operands.

OMP.indication()

The service primitive used by the OMP functional block to signal the client an event with specified parameters.

64.3.10.6 State Diagram

Instantiation of state machines as described is perfomed for all MACs.

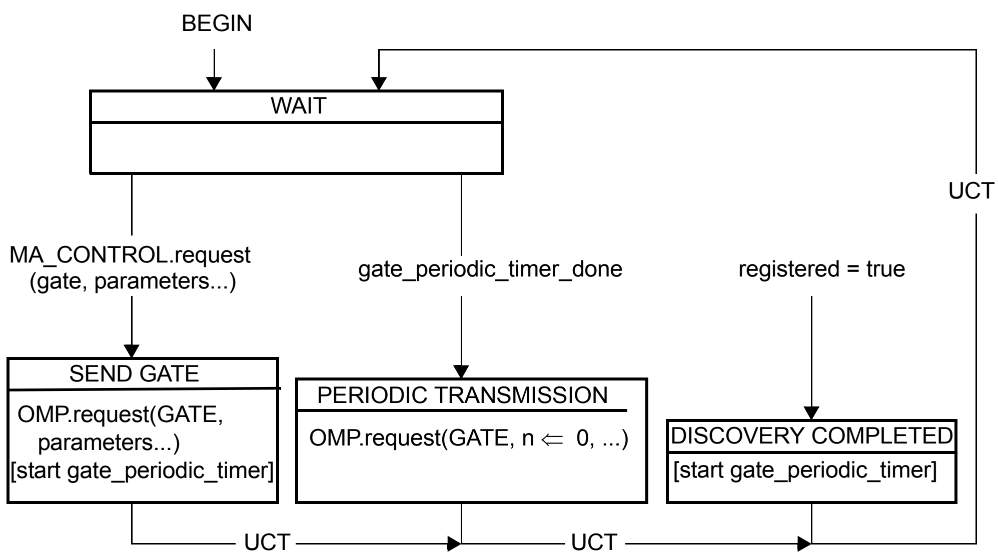


Figure 64–26—Gate Processing State Diagram at OLT

Editor's note (to be removed prior to publication): opcode dependant OMP watchdog

should be moved here for ONU.

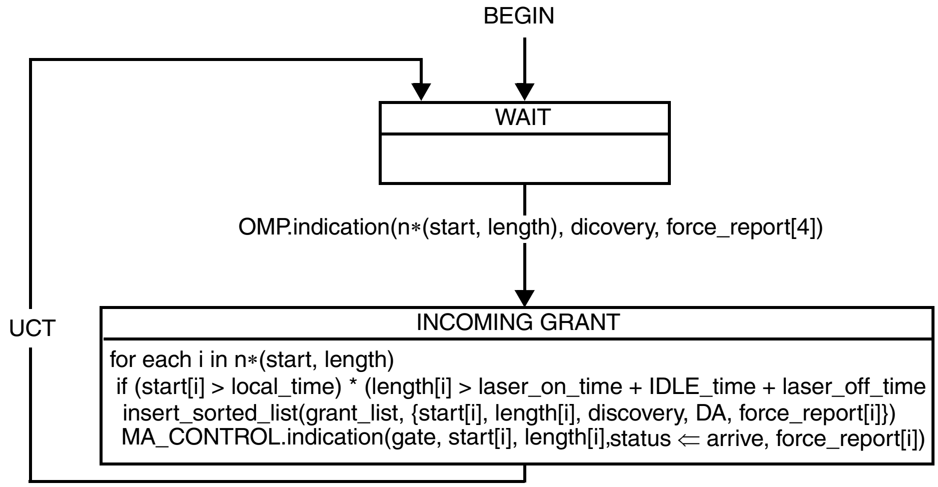


Figure 64–27—Gate Processing ONU Programing State Diagram

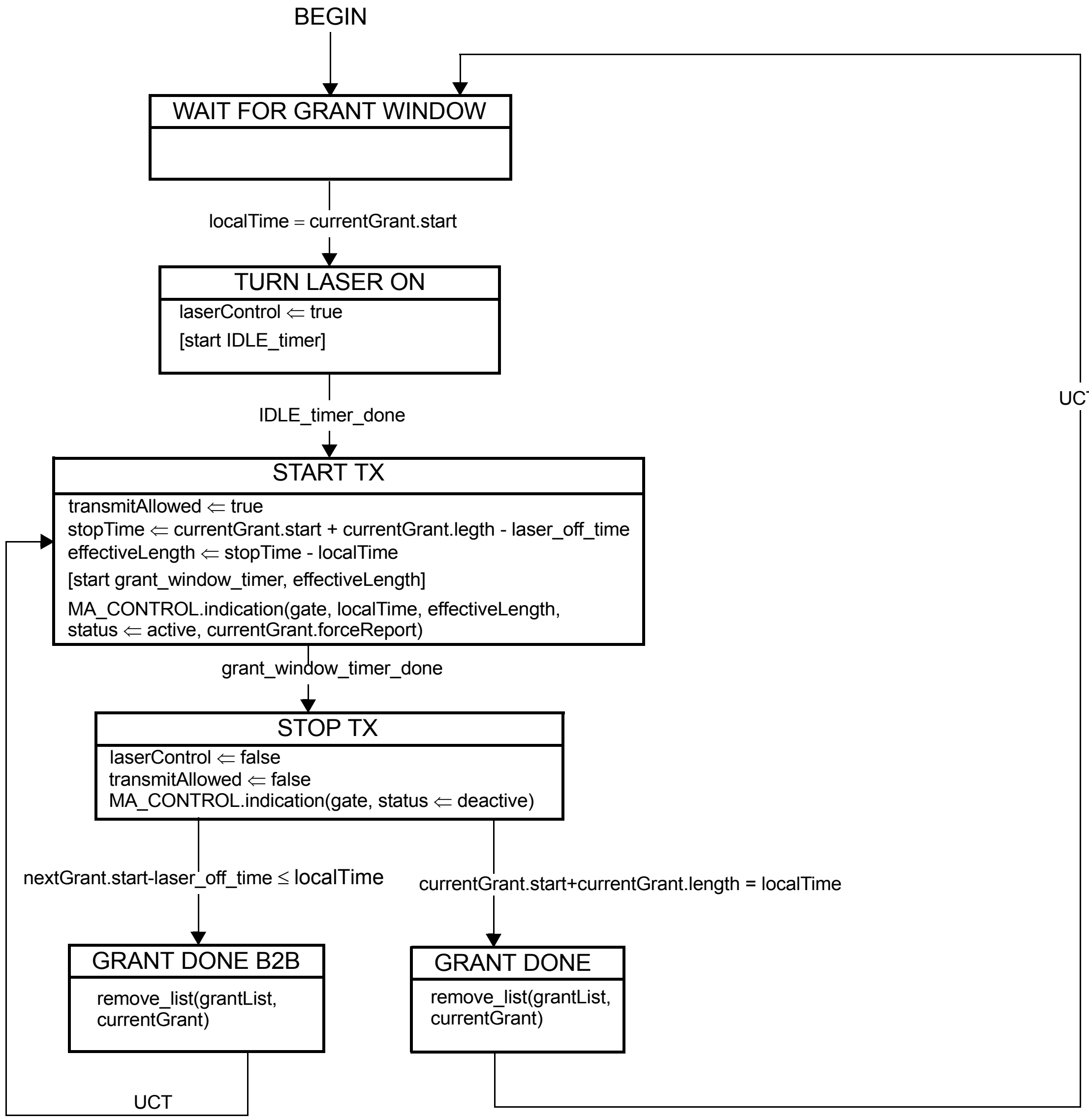


Figure 64–28—Gate Processing ONU Activation State Diagram

64.4 Optical Multi-Point Control Protocol (MPCP)

64.4.1 MPCPDU structure and encoding

Editor's Note: define MPCPDU prior to first mention.

MPCPDU are basic IEEE 802.3 frames; they shall not be tagged (see Clause 3). The MPCPDU structure is shown in Figure 64–29, and is further defined in the following definitions:

a) Destination Adddress (DA). The DA in MPCPDU is the MAC_Control Multicast address as specified in the annexes to #CrossRef# Clause 31, or the individual MAC address associated with the port to which the MPCPDU is destined.

b) Source Address (SA). The SA in MPCPDU is the individual MAC address associated with the port through which the MPCPDU is transmitted.

c) Length/Type. MPCPDUs are always Type encoded, and carry the MAC_Control_Type field value as specified in #CrossRef# subclause 31.4.1.3.

d) Opcode. The opcode identifies the specific MPCPDU being encapsulated. Values are in the range of 2-6, and defined in Table 64–1:

Table 64–1—MPCP Opcodes

MPCPDU	Opcode	Reference
GATE	00-02	64.4.2
REPORT	00-03	64.4.3
REGISTER_REQ	00-04	64.4.4
REGISTER	00-05	64.4.5
REGISTER_ACK	00-06	64.4.6

e) Timestamp. The timestamp field conveys the content of the localTime register at the time of transmission of the MPCPDUs. This field is 32 bits long, and counts 16 bit transmissions. The timestamp counts time in 16 bit time granularity.

f) Data/Reserved/PAD. These 40 octets are used for the payload of the MPCPDUs. When not used they would be filled with zeros on transmission, and be ignored on reception.

g) FCS. This field is the Frame Check Sequence, typically generated by the underlying MAC.

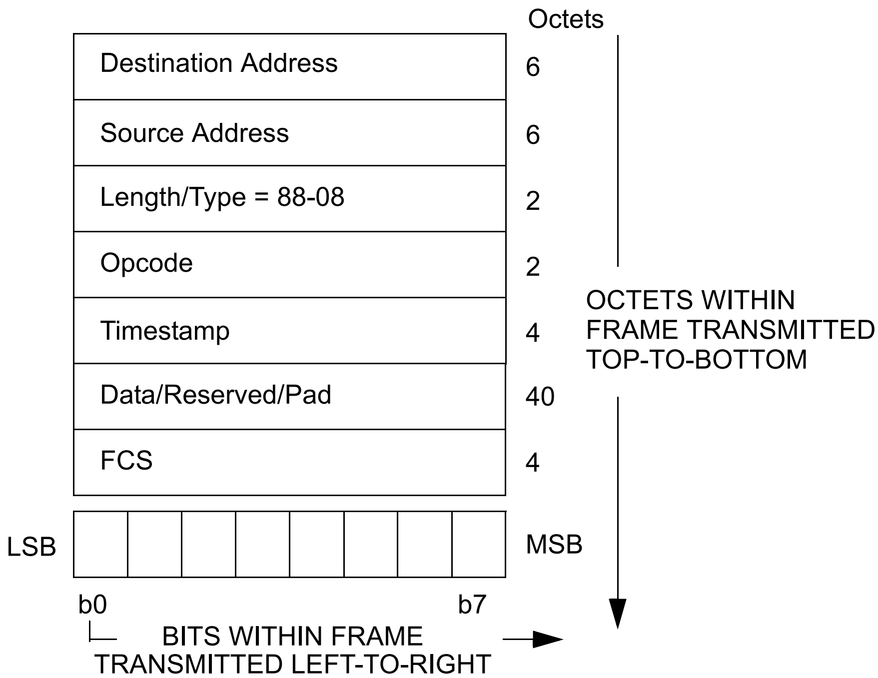


Figure 64–29—Generic MPCPDU

64.4.2 GATE description

The purpose of GATE message is to grant transmission windows to ONUs for both discovery messages and normal transmission. Up to four grants can be included in a single gate message. The number of grants can also be set to zero for using the GATE message as an MPCP keep alive from OLT to the ONU.

The GATE MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the GATE MPCPDU is 00-02.

b) Flags. This is an 8 bit bitfield flag register that holds the following flags:

Table 64–2—GATE MPCPDU Number of grants/Flags Fields

Bit	Flag Field	Values
0-2	Number of grants	0-4
3	Discovery	0 - Normal gate 1 - Discovery gate
4	Force Report Grant 1	0 - No action required 1 - A REPORT frame should be issued at the corresponding transmission opportunity indicated in this GATE
5	Force Report Grant 2	0 - No action required 1 - A REPORT frame should be issued at the corresponding transmission opportunity indicated in this GATE
6	Force Report Grant3	0 - No action required 1 - A REPORT frame should be issued at the corresponding transmission opportunity indicated in this GATE
7	Force Report Grant 4	0 - No action required 1 - A REPORT frame should be issued at the corresponding transmission opportunity indicated in this GATE

The Number of grants field contains the number of grants, composed of valid Length, Start Time pairs in this MPCPDU. This is a number between 0 and 4. Note: when Number of grants is set to 0, sole purpose of message is conveying of timestamp to ONU.
The Discovery flag field indicates that the signaled grants would be used for the discovery process.
The Force Report flag fields ask the ONU to issue a REPORT message related to the corresponding grant number at the corresponding transmission opportunity indicated in this GATE.

c) Grant #n Length. Length of the signaled grant, this is an 16 bit unsigned field. The length is counted in 16 bit time increments. There are 4 Grants that are possibly packed into the GATE MPCPDU. The laser_on_time, IDLE_time, and laser_off_time are included in and thus consume part of Grant #n Length.
d) Grant #n Start Time. Start time of the grant, this is an 32 bit unsigned field. The start time is compared to the local_clock, to correlate the start of the grant. Transmitted values shall satisfy the formula: Grant #n Start Time < Grant #n+1 Start Time.
e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. During the synchronization time the ONU shall send IDLE code-pairs. The value is counted in 16 bit time increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS. This field is present only when the gate is a discovery gate, as signaled by the Discovery flag and is not present otherwise.
f) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation. The size of this field depends on the used Grant #n Length/Start Time entry-pairs, and varies in length from 13 to 39 accordingly.

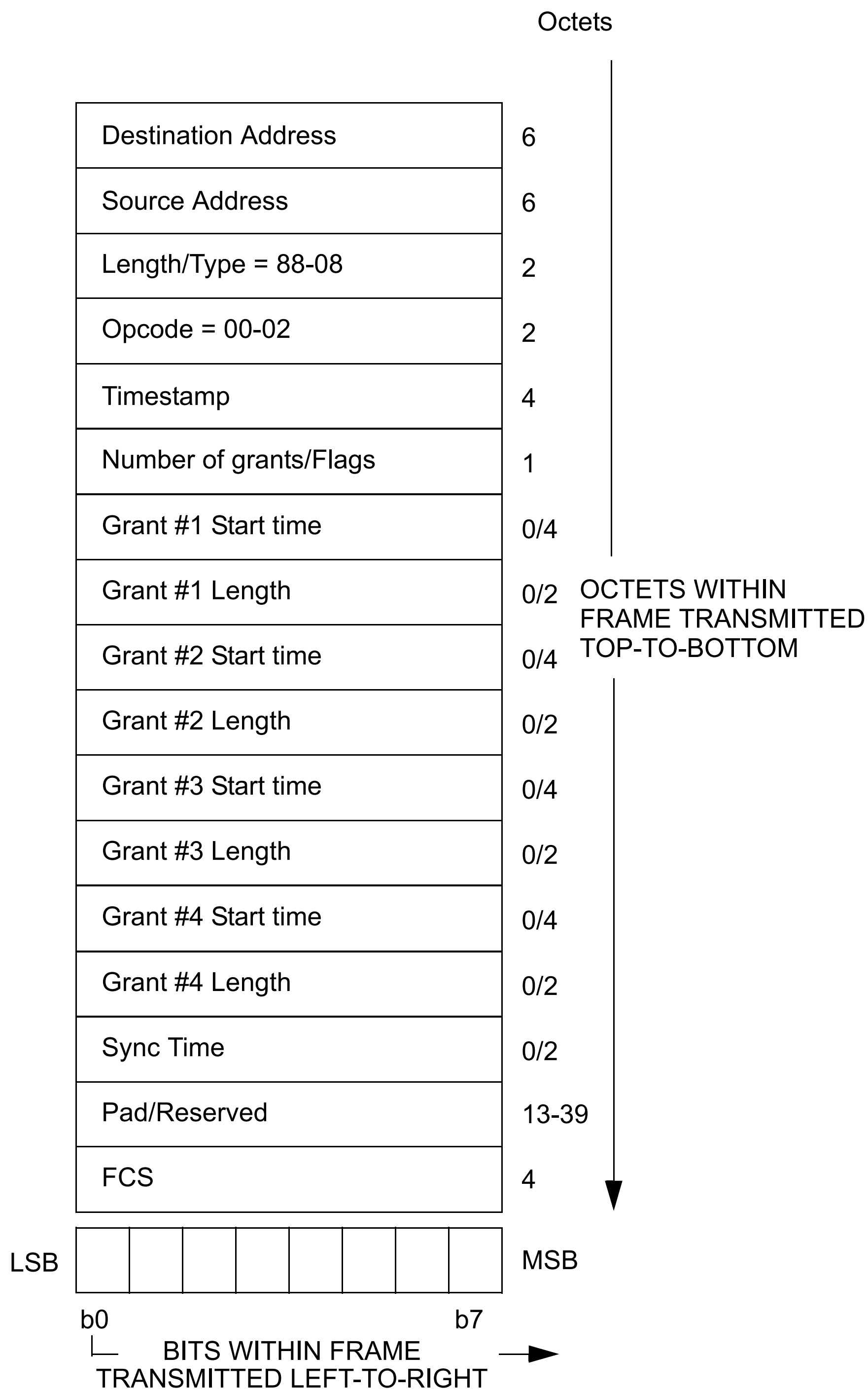


Figure 64–30—GATE MPCPDU

64.4.3 REPORT description

REPORT messages have several functionalities. Time stamp in each REPORT message is used for round trip (RTT) calculation. In the REPORT messages ONUs indicate the number of bytes they request per 802.1Q priority queue. REPORT messages are also used as keep alives from ONU to OLT. ONUs shall issue

REPORT message periodically in order to maintain link health at the OLT as defined in 64.3.9. In addition, the OLT may specifically request a REPORT message.

The REPORT MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REPORT MPCPDU is 00-03.
b) Number of Queue Sets. This field specifies the number of requests in the Report message. A Report frame may hold multiple sets of Report bitmap and Queue #n as specified in the Number of Queue Sets field
c) Report bitmap. this is an 8 bit bitfield flag register that indicates which queues are represented in this REPORT MPCPDU.

Table 64–3—REPORT MPCPDU Report bitmap fields

Bit	Flag Field	Values
0	Queue 0	0 - queue 0 report is not present 1 - queue 0 report is present
1	Queue 1	0 - queue 1 report is not present 1 - queue 1 report is present
2	Queue 2	0 - queue 2 report is not present 1 - queue 2 report is present
3	Queue 3	0 - queue 3 report is not present 1 - queue 3 report is present
4	Queue 4	0 - queue 4 report is not present 1 - queue 4 report is present
5	Queue 5	0 - queue 5 report is not present 1 - queue 5 report is present
6	Queue 6	0 - queue 6 report is not present 1 - queue 6 report is present
7	Queue 7	0 - queue 7 report is not present 1 - queue 7 report is present

d) Queue #n Report. This field conveys the status of queue number n as transmitted by the ONU. It is present only when the corresponding flag in the Report bitmap is set. The granularity of Queue #n report is 2 octets.
e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation. The size of this field depends on the used Queue Report entries, and accordingly varies in length from 0 to 39.

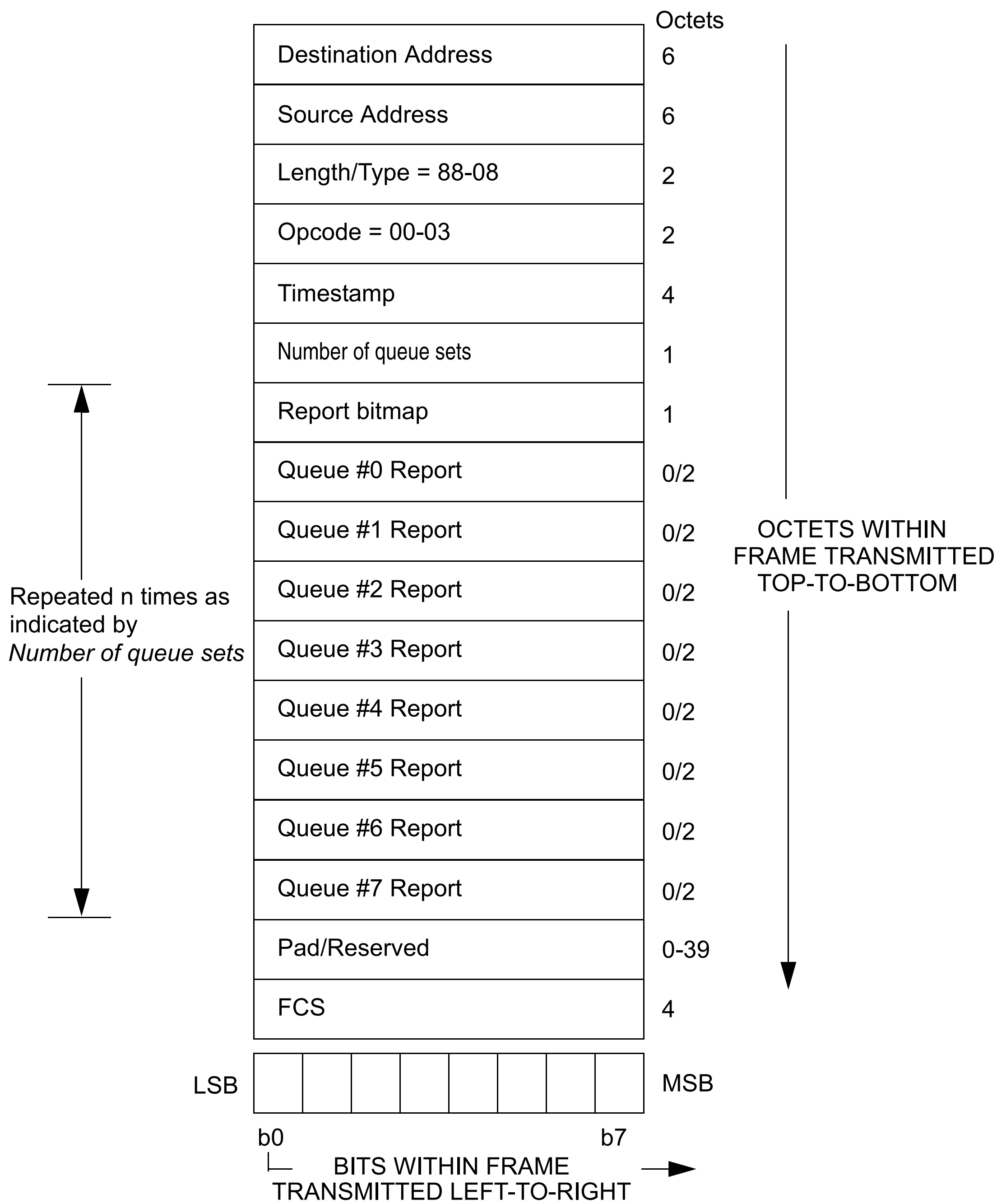


Figure 64–31—REPORT MPCPDU

64.4.4 REGISTER_REQ description

The REGISTER_REQ MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_REQ MPCPDU is 00-04.

b) Flags. this is an 8 bit flag register that indicates special requirements for the registration.

Table 64–4—REGISTER_REQ MPCPDU Flag fields

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Register	Registration attempt for ONU.
2	Reserved	Ignored on reception.
3	Deregister	This is a request to deregister the ONU. Subsequently, the MAC is deallocated and the LLID may be reused.
4-255	Reserved	Ignored on reception.

c) Pending grants. This is an unsigned 8 bit value signifying the number of future grants the ONU may buffer before activating. The OLT should not grant the ONU more than Pending grants into the future.

d) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation.

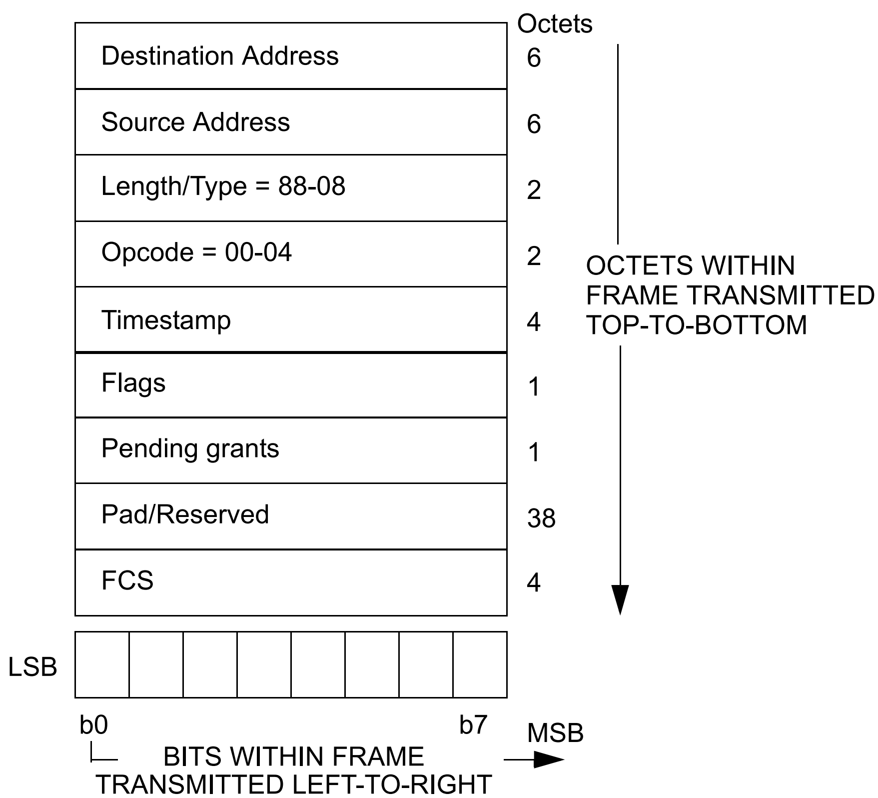


Figure 64–32—REGISTER_REQ MPCPDU

64.4.5 REGISTER description

The REGISTER MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) DA. The destination address used shall be an individual MAC address.
b) Opcode. The opcode for the REGISTER MPCPDU is 00-05.
c) Assigned Port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.
d) Flags. this is an 8 bit flag register that indicates special requirements for the registration.

Table 64–5—REGISTER MPCPDU Flags field

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Reregister	The ONU is explicitly asked to re-register.
2	Deregister	This is a request to deallocate the port and free the LLID. Subsequently, the MAC is deallocated.
3	Ack	The requested registration is successful.
4	Nack	The requested registration attempt is denied by the higher-layer-entity.
5-255	Reserved	Ignored on reception.

e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. During the synchronization time the ONU shall send IDLE code-pairs. The value is counted in 16 bit time increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS.
f) Echoed pending grants. This is an unsigned 8 bit value signifying the number of future grants the ONU may buffer before activating. The OLT should not grant the ONU more than Pending grants into the future.
g) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation.

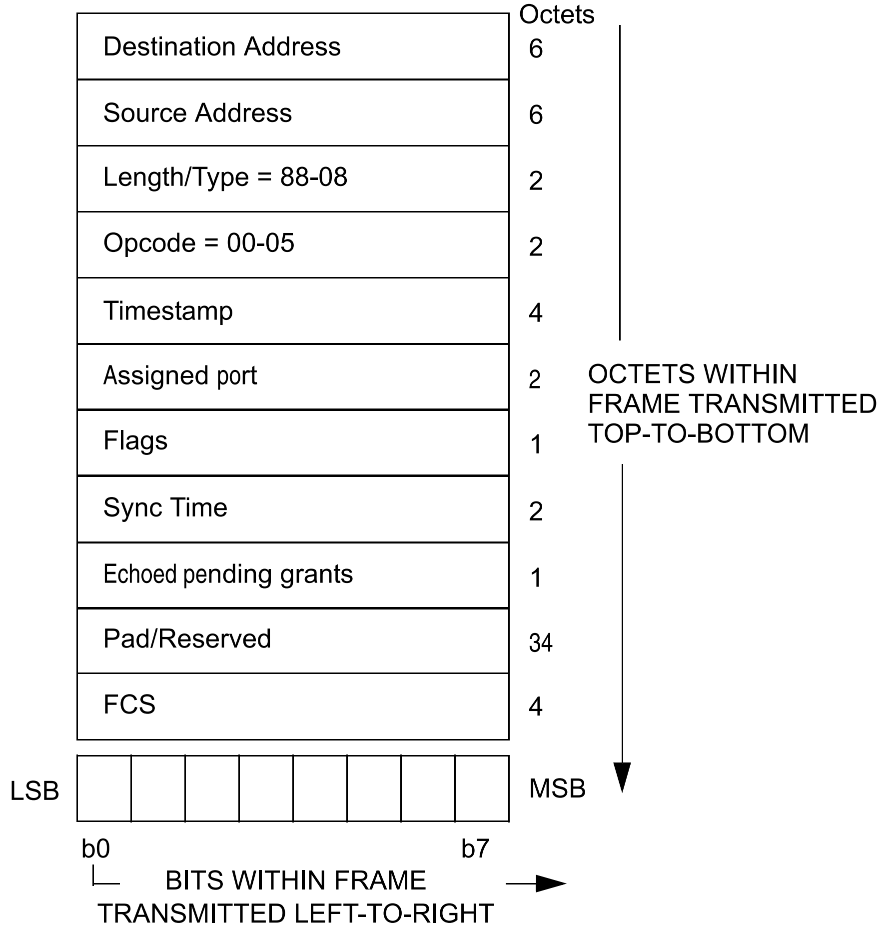


Figure 64–33—REGISTER MPCPDU

64.4.6 REGISTER_ACK description

The REGISTER_ACK MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_ACK MPCPDU is 00-06.

b) Flags. this is an 8 bit flag register that indicates special requirements for the registration.

Table 64–6—REGISTER_ACK MPCPDU Flag fields

Value	Indication	Comment
0	Nack	The requested registraton attempt is denied by the higher-layer-entity.
1	Ack	The registration process is successfully acknowl-edged
2-255	Reserved	Ignored on reception

c) Echoed assigned port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.

d) Echoed Sync Time. This is an unsigned 16 bit value echoing the required synchronization time of the OLT receiver as previously advertised. During the synchronization time the ONU shall send IDLE code-pairs. The value is counted in 16 bit time increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS.

e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception when constructing a complying MPCP protocol implementation.

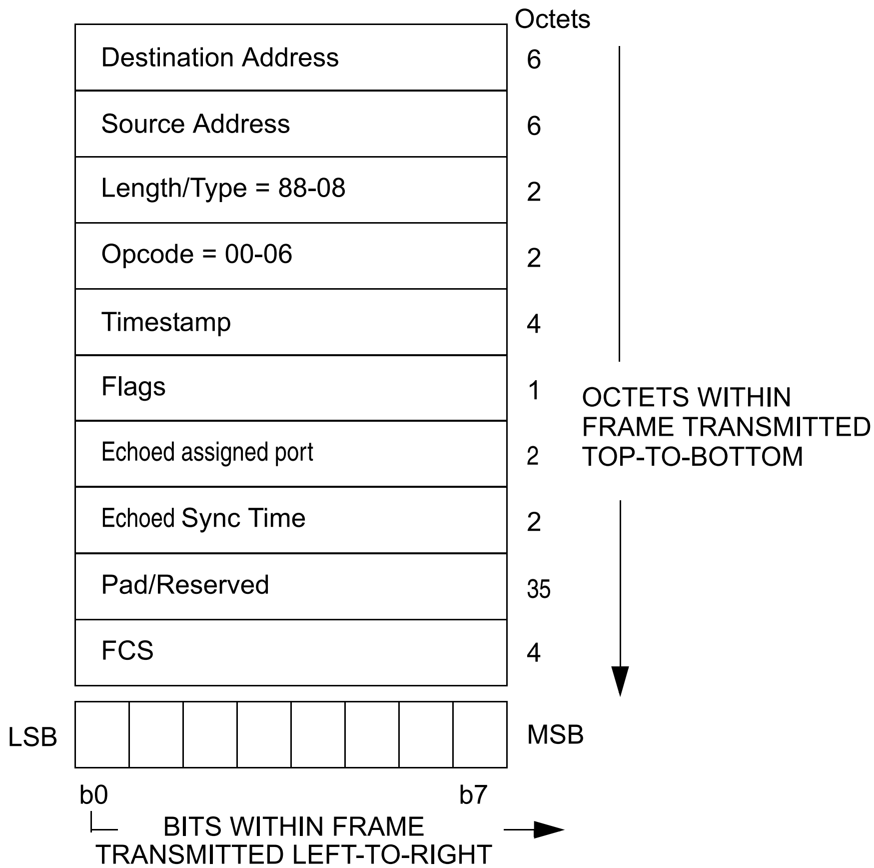


Figure 64–34—REGISTER_ACK MPCPDU

64.5 Protocol Implementation Conformance Statement (PICS) proforma for Clause 56, Multi-Point MAC Control[1]

Editor's note: To be removed prior to publication. PICS not done yet.

64.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 56 Optical Multi-Point, shall complete the following Protocol Implementation Conformance Statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

[1]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

64.5.2 Identification

64.5.2.1 Implementation identification

Supplier	
Contact point for enquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Names(s)	
NOTES 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

64.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3ah-2003, Clause 56, Multi-Point MAC Control
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to the standard.)	

Date of Statement	

64.5.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
MF	MPCP			M	Yes [ ]
*O				M	Yes [ ] No [ ]
*O				M	Yes [ ] No [ ]

64.5.2.4 General

Item	Feature	Subclause	Value/Comment	Status	Support
				M	Yes [ ]
				M	Yes [ ]

65. Extensions of the Reconciliation Sublayer (RS) for Point to Point Emulation and extensions of the 1000BASE-X PHY for Forward Error Correction for Multipoint Optical Links

Editors' Notes: To be removed prior to final publication.

The text "CROSS REF" is used to signify a cross reference to another clause within 802.3. The chief editor may use this as a search string when compiling the draft standard.

References:

ITU-T Recommendation G.975

Definitions:

None.

Abbreviations:

None.

Issues:

None.

Revision History:

Draft 0.9	June 2002	Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.0	August 2002	Preliminary draft for IEEE P802.3ah Task Force review.
Draft 1.1	October 2002	Draft for IEEE P802.3ah Task Force review.
Draft 1.2	November 2002	Complete rewrite for IEEE P802.3ah/D1.2. Clause 35 is referenced, not duplicated. Title is changed to reflect addition of FEC to this clause. FEC is added.
Draft 1.3	January 2003	Add reference above for ITU-T Recommendation G.975 Replace "byte" with "octet" throughout clause Fix various spelling mistakes Make various formatting & wording changes Add definition for MLM laser Be more precise about defining octet order when describing the FEC frame and the shortened frame Change /T_FEC/ to /T_FEC_E/ & /T_FEC_O/ Change content of /S_FEC/ Add S_FEC & T_FEC to Figure 57-4 Replace "Multiplexing MAC Control" with "Multi-Point MAC Control" Change broadcast MAC to multicast MAC then add a single broadcast MAC with 7FFF LLID Replace "llid" parameter with "logical_link_id" Move CRC8 check earlier in the preamble parsing description Clean up coloring and strikethroughs Clarify FEC objectives Remove one of the arrows in Fig 57-1 from MAC Control to RS. Add desciptions to block diagrams Add new state diagrams Change clause numbering Moved burst mode extensionsto PMA from 36 to 65. Updated value per Vancouver motion.

Editors' Notes: To be removed prior to final publication.

Revision History continued:

Draft 1.414 April 2003	Change text in 65.1.2 Broadcast MAC to receive MODE=0, LLID=0x7fff packets for registration request Replace MPC_LLID primitive with variables, statically assigned to each MAC Replace "normal preamble" with "normal inter-frame" when discarding packets Clarify that SPD is always in 3rd octet of preamble Add cross reference to 4.2.8 in 65.2.1 Add statement that, if FEC is used in GE-PON, it shall be this FEC Correct spelling of "occuring", twice Change "d" from 12 to 10 Correct spelling of "descibed" Modify Figure 65-6 so Packet Boundary Detector controls selector, doesn't send data Modify Figure 65-5 to use ftx_code-group instead of tx_code-group to FEC from PCS Replace "1553-octet buffer" with desciption of minimum fields to buffer Replace "Packetthat" with "Packets that" Modify Figure 65-8 to remove selector & fifo and fixed non_fec latency Add many new variable/functions/counter definitions Correct spelling of "aquisition" Add text in 65.2.4.2.1 to descibe that PUDR is used for both input and output TX timing. Modify Figure 65-10: remove COMMA_DETECT_5, 9 errors loses sync, use good_cgs Modify Figure 65-9: Fix XMIT_IPG to XMIT_IPG transition Modify Figure 65-8: Use new /S_FEC/, don't include /S/ in error correction Split Figure 65-11 into 2 parts: buffer_fill and buffer_empty

This clause describes functions only for use in a Gigabit Ethernet Passive Optical Network (GE-PON). This type of network requires that the Multi-Point MAC Control sublayer exists above the MACs, as described in *CROSS REF* Clause 64. In a GE-PON network, only full duplex operation is supported.

65.1 Extensions of the Reconciliation Sublayer (RS) for Point to Point Emulation

65.1.1 Overview

This subclause extends *CROSS REF* Clause 35 to enable multiple data link layers to interface with a single physical layer. Figure 65–1 shows the relationship of this extended Reconciliation sublayer to the ISO/IEC OSI reference model.

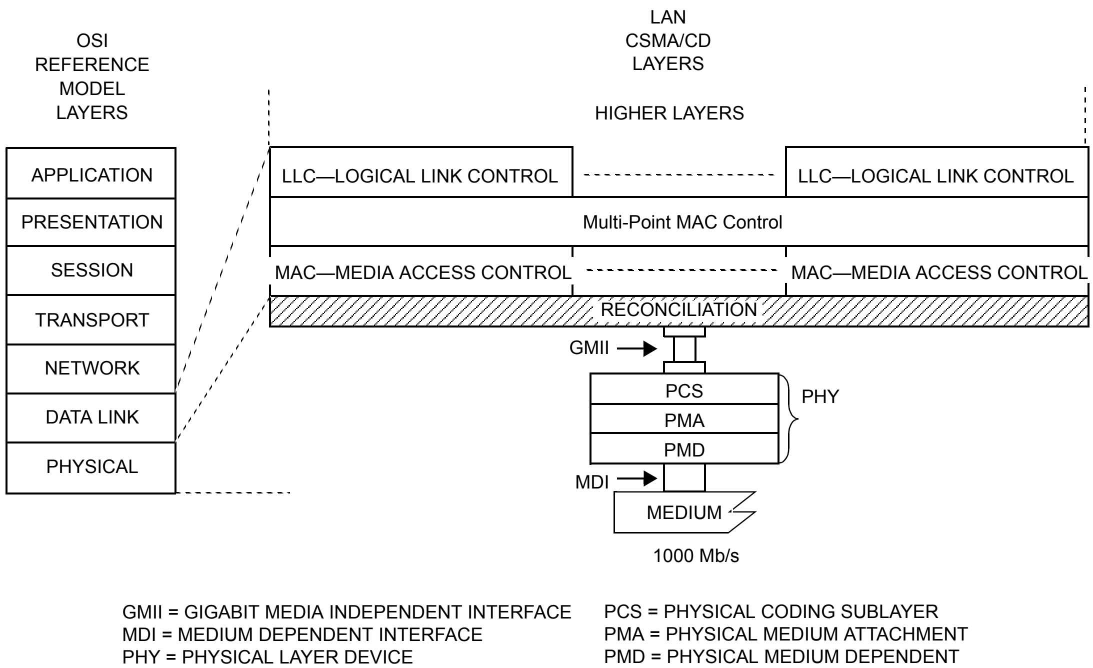


Figure 65–1—RS location in the OSI protocol stack

To support multiple MACs above a single RS, this clause uses an index [j] when selecting a single MAC - MAC[j] - or any of the service primitives associated with that MAC - PLS_data[j].request, etc. The number of MACs supported is limited only by the implementation. It is acceptable for only one MAC to be connected to this RS. The mapping of GMII signals to PLS service primitives is described in *CROSS REF* 35.2.1.

Associated with each MAC is a Logical Link Identifier (LLID) that performs a mapping function for the packets to and from MAC[j]. The assignment of LLID to MAC[j] is performed in the Multi-Point MAC Control sublayer and is described in *CROSS REF* 64.3.8. This clause describes how the LLID is used to identify a packet transmitted from MAC[j] and how received packets are directed to MAC[j].

There are two different instantiations of this sublayer, one in the Optical Line Terminal (OLT) and one in the Optical Network Unit (ONU). In a GE-PON, there is only one OLT and one or more ONUs. The operation of this sublayer is different for these two instantiations. In an OLT, there actually exists two MACs for each assigned LLID value: a unicast MAC and a multicast MAC. The unicast MAC can transmit and receive packets. The multicast MAC can only transmit packets. When it is necessary to differentiate between the unicast and multicast MACs associated with a single LLID, the unicast MAC is referred to as MAC[j,u] and the multicast MAC is referred to as MAC[j,m]. In addition, there is a single broadcast MAC in the OLT with the ability to transmit and receive packets.

In an ONU, there exists only one MAC. While the index [j] is not particularly useful when considering the ONU instance of this sublayer, this instance may be considered merely a special case of the more general OLT instance.

Editors note: *To be removed prior to final publication*

This is the only place that uses MAC[j]. Also, the terms unicast and multicast are considered inappropriate for the description of the MAC pair. Ideas for rewording this section are requested during the comment period.

65.1.2 Functional specifications

The variables below provide a mapping for multiple MACs. While the usage of this mapping is less interesting in the ONU, it is critical in the OLT. This mapping is used to replace transmitted preambles with MODE and LLID fields as well as to steer received packets to the appropriate MAC.

65.1.2.1 Variables associated with the sublayer

type
Value: 1 bit
This variable shall be 1 for an OLT and shall be 0 for an ONU.

65.1.2.2 Variables associated with each MAC

enable
Value: Boolean
This variable shall be TRUE for an ONU MAC. For an OLT MAC, this variable is defined as below:
TRUE when management has assigned a value to mode and logical_link_id. Indicates the MAC is enabled to receive frames.
FALSE when the MAC is not in use.

mode
Value: 1 bit
This variable shall be 0 for an OLT unicast MAC and shall be 1 for an OLT multicast MAC and the broadcast MAC. This variable shall be 0 for an ONU MAC.

logical_link_id
Value: 15 bits
This variable shall be set to the broadcast value of 0x7FFF for the OLT's broadcast MAC and for the ONU MAC until it is registered (see *CROSS REF* 64.3.8). Unicast and multicast MACs are enabled in pairs and shall share a common logical_link_id value.

65.1.2.3 Transmit

The transmit function of this extended RS replaces some of the octets of the preamble as transmitted by the MAC with several fields: SPD, LLID and CRC8. The SPD field is used by the receiver function to locate the LLID and CRC8 fields. The LLID field identifies the source or destination MAC. The CRC8 field provides a level of integrity on the LLID field. Table 65–1 shows the replacement mapping.

Table 65–1—Preamble replacement mapping

Offset	Field	Preamble	Modified preamble
1	-	0x55	same
2	-	0x55	same
3	SPD	0x55	0xd5
4	-	0x55	same
5	-	0x55	same
6	LLID[15:8]	0x55	<mode,logical_link_id[14:8]>[a]
7	LLID[7:0]	0x55	<logical_link_id[7:0]>[b]
8	CRC8	0xd5	The 8 bit CRC calculated over offsets 3 through 7

[a]mode maps to TXD[7], logical_link_id[14] maps to TXD[6], logical_link_id[8] maps to TXD[0]
[b]logical_link_id[7] maps to TXD[7], logical_link_id[0] maps to TXD[0]

65.1.2.3.1 SPD

The SPD field is one octet in length and replaces the third octet of the preamble. The 1000BASE-X PCS transmit function replaces the first octet of preamble with the /S/ code-group or it discards the first octet and replaces the second octet of preamble with the /S/ code-group. This decision is based upon the even or odd alignment of the PCS's transmit state diagram (see *CROSS REF* Figure 36-5). The 1000BASE-X PCS receive function replaces the /S/ code-group with an octet of preamble. The third octet of preamble is the first octet passed through the 1000BASE-X PHY without modification.

65.1.2.3.2 LLID

The LLID field is two octets in length and replaces the last two octets of preamble. The LLID field is a concatenation of the mode and logical_link_id variables for the associated MAC.

65.1.2.3.3 CRC-8

A cyclic redundancy check (CRC) is used to generate a CRC value for the CRC8 field. The CRC8 field contains an 8-bit CRC value. This value is computed as a function of the contents of the modified preamble beginning with the SPD field (offset 3) through the LLID field (offset 7). The encoding is defined by the following generating polynomial:

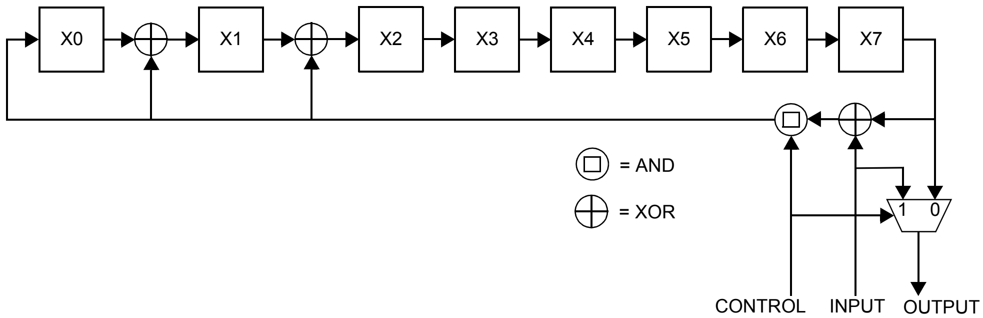
$$G(x) = x^8 + x^2 + x + 1 \qquad (65\text{-}1)$$

This CRC calculation shall produce the same result as the serial implementation shown in Figure 65–2.

65.1.2.4 Receive function

The receive function of this extended RS is responsible for the following functions:

a) locate the SPD field;
b) use the location of the SPD field to locate the CRC8 field and verify that the received value matches the CRC calculated using the received data;
c) use the location of the SPD field to locate the LLID field and parse it to determine the index of the destination MAC;



CONTROL = 1 when shifting the modified preamble and calculating the CRC
CONTROL = 0 when transmitting the CRC8 field
Before calculation begins, the shift register is initialized to 0x00.

Figure 65–2—CRC8 field generation

d) if the packet is not discarded due to incorrect CRC or unknown LLID, then replace the SPD and LLID fields with normal preamble and the CRC8 field with the SFD and transfer the packet to the appropriate MAC;
e) otherwise, discard the entire packet, replacing it with normal inter-frame.

Table 65–2 shows the mapping of the modified preamble to RXD.

Table 65–2—Preamble replacement mapping

Signal	Bit values of octets received through GMII[a]									
RXD0	X	1[b]	1	1[c]	1	1	logical_link_id[8][d]	logical_link_id[0][e]	X7[f]	D0[g]
RXD1	X	0	0	0	0	0	logical_link_id[9]	logical_link_id[1]	X6	D1
RXD2	X	1	1	1	1	1	logical_link_id[10]	logical_link_id[2]	X5	D2
RXD3	X	0	0	0	0	0	logical_link_id[11]	logical_link_id[3]	X4	D3
RXD4	X	1	1	1	1	1	logical_link_id[12]	logical_link_id[4]	X3	D4
RXD5	X	0	0	0	0	0	logical_link_id[13]	logical_link_id[5]	X2	D5
RXD6	X	1	1	1	1	1	logical_link_id[14]	logical_link_id[6]	X1	D6
RXD7	X	0	0	1	0	0	mode	logical_link_id[7]	X0	D7
RX_DV	0	1	1	1	1	1	1	1	1	1

[a]Leftmost octet is the first received
[b]This octet may be missing per 1000BASE-X PCS transmit state diagram (see *CROSS REF* Figure 36-5)
[c]SPD field
[d]First octet of LLID field
[e]Second octet of LLID field
[f]CRC8 field
[g]D0 through D7 is the first octet of the PDU (first octet of the Destination Address)

65.1.2.4.1 SPD

Recall that the 1000BASE-X transmit function must maintain an even alignment for its Start_of_Packet delimiters. It may replace the first octet of preamble with the /S/ code-group and pass the second octet unchanged or it may discard the first octet of preamble and replace the second octet of preamble with the /S/ code-group. Either way, the SPD is always passed without modification. These shall be the only two possibilities considered when parsing the incoming octet stream for the SPD. If the SPD field isn't found then the packet shall be discarded. If the packet is transferred, the SPD shall be replaced with a normal preamble octet and the one or two octets preceding the SPD and the two octets following the SPD are passed without modification.

65.1.2.4.2 LLID

The third and fourth octets following the SPD contain the mode and logical_link_id values. These values are acted upon differently for OLTs and ONUs.

If the device is an OLT then the received mode bit is ignored. The received logical_link_id value is compared against the logical_link_id variables from all enabled unicast MACs as well as the broadcast value. If no match is found then the packet shall be discarded. If a match is found with an enabled unicast MAC's logical_link_id variable, then the packet is destined to that MAC. If the matched value is the broadcast value, then the packet is destined for the Broadcast MAC.

If the device is an ONU then the following comparison is made:

a) if the received mode bit is 0 and the received logical_link_id value matches the logical_link_id variable then the comparison is considered a match;
b) if the received mode bit is 1 and the received logical_link_id value doesn't match the logical_link_id parameter, or the received logical_link_id matches the broadcast value, then the comparison is considered a match.

If no match is found then the packet shall be discarded. If a match is found, then the packet is intended to be transferred.

If the packet is transferred, then both octets of the LLID field shall be replaced with normal preamble octets.

65.1.2.4.3 CRC-8

The octet following the LLID field contains the CRC8 field. The value of this field is compared against the calculated CRC of the received octets, beginning with the SPD field and ending with the last octet of the LLID field. If the received and calculated CRC values do not match, then the packet shall be discarded. If the values match then the packet is transferred. If the packet is transferred, then the CRC8 field shall be replace with the SFD.

65.2 Extensions of the 1000BASE-X PHY for Forward Error Correction for Multi-point Optical Links

65.2.1 Overview

An optical multi-point network connects multiple DTEs using a single shared fiber. The architecture is asymmetrical, based on a tree and branch topology utilizing passive optical splitters. The topology, also known as a Passive Optical Network (PON) is here applied to the Gigabit Ethernet architecture creating a Gigabit Ethernet Passive Optical Network (GE-PON). This subclause deals with an optional mechanism to implement a Forward Error Correction (FEC) code into the Ethernet framework to increase the optical link budget or the fiber distance using an Multi-Longitudinal Mode (MLM) transmitter in the uplink reducing the Mode Partition Noise (MPN) penalty.

The FEC appends to the Ethernet frame additional data that is a result of a set of non-binary arithmetic functions (known as Galois arithmetic) performed on the data of the Ethernet frame. This additional data (known as the FEC parity octets) is used to correct errors at the receiving end of the link that may occur when the data is transferred through the link. The MAC layer performs rate adaptation, stretching the IPG to provide the necessary space at the end of the Ethernet frame for the parity octets, as described in 4.2.8.

The FEC sublayer is located between the PCS and the PMA and may be implemented with a Ten Bit Interface (TBI) to both sides. Though the FEC functionality and the FEC sublayer are optional, a FEC sublayer implemented for operation over a multi-point optical link shall behave as specified in 65.2.

At transmission, the FEC sublayer receives the packets from the PCS, performs the FEC coding, replaces some of the stretched IPG with parity octets, and sends the data to the PMA. At reception, the FEC sublayer receives the data from the PMA, does the octet alignment, aligns on the frame, decodes the FEC code, inserts idles instead of the parity octets and sends the data to the PCS.

65.2.1.1 Objectives

The following are the objectives of FEC:

a) Keep frame format compliance to 1000BASE-X PCS;
b) Support optional functionality;
c) Allow backwards compatibility with legacy 1000BASE-X devices;
d) Support BER objective of 10e-12 at PCS;
e) Support BER objective of 10e-4 at FEC sublayer.

65.2.1.2 Position of optical multipoint FEC within the IEEE 802.3 hierarchy

The FEC sublayer is architecturally positioned between the PCS and PMA sublayer of the Physical Layer of the ISO/IEC OSI reference model as shown in Figure 65–3.

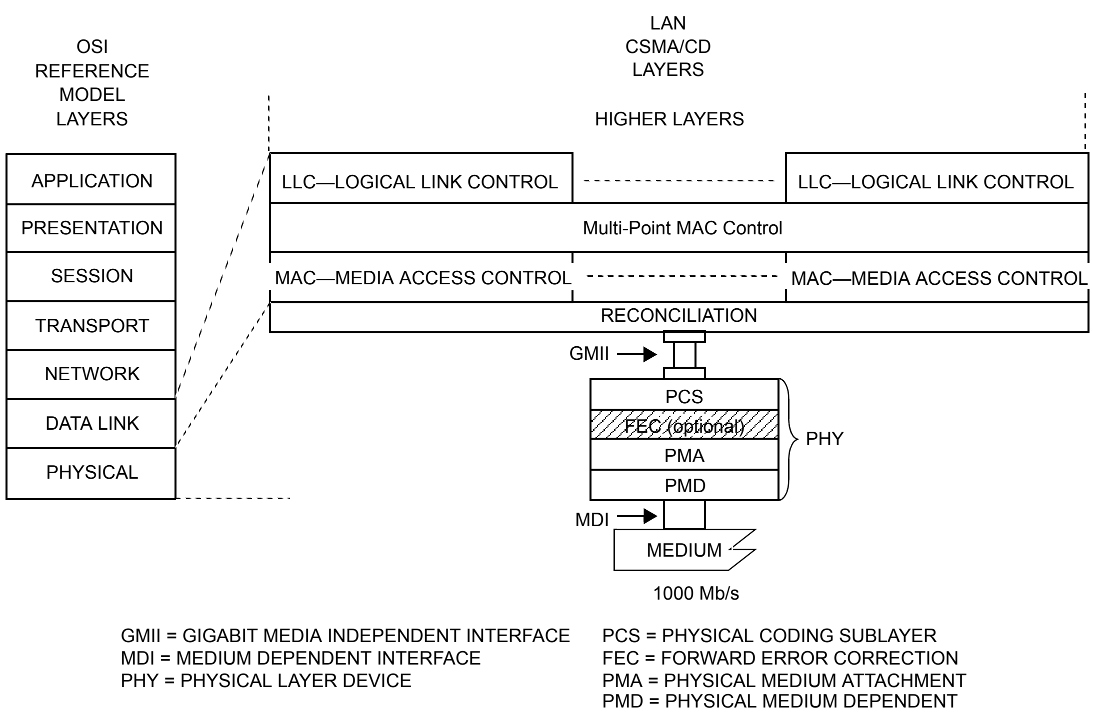


Figure 65–3—FEC location in the OSI protocol stack

65.2.2 Forward error correction code

The FEC code specification, properties and performance analysis are specified in the "ITU-T Recommendation G.975".

The FEC code used is a linear Cyclic Block code - the Reed-Solomon code (255,239,8) over the Galois Field of GF(2^8) - a non-binary code operating on 8-bit symbols. The code encodes 239 symbols and adds 16 parity symbols. The code is systematic - meaning that the information symbols are part of the code word.

The code is the systematic form of the code $G(x) = \prod_{i=0}^{15}(x-\alpha^i)$

where α is equal to 0x02.

A code word of the systematic code is presented by D(x) + P(x) = G(x) * L(x) where:

D(x) is the data vector - $D(x)=D_{238}X^{254} + ... + D_0X^{16}$. D_{238} is the first data octet and D_0 is the last.

P(x) is the data vector - $P(x)=P_{15}X^{15} + ... + P_0$. P_{15} is the first parity octet and P_0 is the last.

A data octet (d_7, d_6, ..., d_1, d_0) is identified with the element: $d_7*\alpha^7 + d_6*\alpha^6 + ... d_1*\alpha^1 + d_0$ in GF(2^8), the finite field with 2^8 elements. The code has a correction capability of up to eight symbols. Note that for the (255,239) Reed Solomon code, the symbol size equals one octet.

65.2.3 FEC frame format

The frame format of an FEC code Ethernet frame is herein described.

65.2.3.1 Placing parity octets

The Ethernet frame is received from the PCS. The data is partitioned into 239 symbol frames (FEC frames), with the first frame beginning with the first symbol after the /S_FEC/ ordered_set and the last frame ending with the last symbol before the /T_FEC/ ordered_set. Each 239 symbol FEC frame is encoded using the (255,239) Reed Solomon encoder which results in an additional 16 parity symbols for each FEC frame. The 239 symbol FEC frame plus the associated 16 parity symbols form the 255 symbol Reed Solomon codeword. The additional 16 parity symbols, which are generated from this encoding process for each FEC frame, are gathered and added at the end of the packet. The entire packet is encoded including the preamble (with special P2MP fields), address and FCS.

65.2.3.2 Shortened last frame

When dividing the data into 239 symbol frames there might be a case where the last frame is shorter than 239 symbols. This frame is noted as a shortened frame. A shortened frame of length r octets results in the data vector assignment of D_{238} to D_r as zeros and D_{r-1} to D_0 as valid data, where D_{r-1} is the first octet of the shortened frame and D_0 is the last. This full size FEC frame is then encoded and the 16 parity symbols are generated. The data is then sent without the zero symbols. At the receiver, the decoder completes the frame again into the full 239 symbol FEC frame (by adding back the zeroes) for decoding.

Hence, the number of additional parity octets added for every Ethernet frame are:

$$L_{parity} = 16 \times ceil\left(\frac{L_{Ethernet} + L_{preamble} + L_{FCS}}{239}\right) \qquad (65\text{-}2)$$

65.2.3.3 Special frame markers

The Ethernet frame consists of a number of FEC frames plus special frame start and stop markers. In order to decode the FEC code, the receiver must first synchronize on the Ethernet frame. Therefore, the Ethernet frame markers are not protected by the FEC code and are exposed to higher BER. Therefore, special start and stop marker symbols are added at the beginning and the end of the FEC coded frame that are capable of being correctly detected in a high noise environment. The special symbol noise immunity is made possible by the implementation of a simple correlator. The marker framing sequence used is 6 octets long and the sequence is long enough to be detected with very high probability. The start FEC frame framing sequence is denoted by /S_FEC/ and the end of FEC frame framing sequence is denoted by /T_FEC/.

In order to determine that an FEC coded frame has started, the input symbol stream is scanned for a match with the /S_FEC/ ordered_set and, when the match has less than d/2 errors, sync is considered to have been achieved. In order to determine that an FEC coded frame has ended, the input symbol stream is scanned for a match with the /T_FEC_O/ or /T_FEC_E/ ordered_sets with fewer than d/2 errors.

The value chosen for d is 10, the number of bits that are different between these ordered_sets and any other regularly occurring 5 consecutive code-groups when considered in the 10-bit domain.

The sequence can flow through non-FEC PCS transparently (in a False_Carrier_Sense mode).

The start and stop symbols are constructed from 8B/10B code-groups. The definition of the symbols is:

— /S_FEC/ - start of FEC coded packet - /K28.5/D6.4/K28.5/D6.4/S/
— /T_FEC_E/ - end of FEC coded packet with even alignment - /T/R/I/T/R/
— /T_FEC_O/ - end of FEC coded packet with odd alignment - /T/R/R/I/T/R/

The /I/ in both the /T_FEC_E/ and the /T_FEC_O/ ordered_sets can be either an /I1/ (a disparity correcting IDLE) or an /I2/ (a disparity neutral IDLE).

Figure 65–4 describes the FEC coded Ethernet frame. Between the FCS and PARITY fields, the T_FEC can be either the /T_FEC_E/ or the /T_FEC_O/ ordered_set. After the PARITY field, the T_FEC can only be a /T_FEC_E/ ordered_set.

S_FEC	PREAMBLE	FRAME	FCS	T_FEC	PARITY	T_FEC

Figure 65–4—FEC coded Ethernet Frame

65.2.4 FEC sublayer operation

This section describes the functionality and operation of the FEC sublayer.

65.2.4.1 Principles of operation

At transmission, the FEC sublayer receives the packets from the PCS, performs the FEC coding, appends the parity octets in place of the stretched IPG and sends the data to the PMA. At reception, the FEC sublayer receives the data from the PMA, performs the octet alignment, detects the Start FEC Framing Sequence, decodes the FEC code, correcting data where necessary and possible, replaces the parity octets with IDLE and sends the data to the PCS.

65.2.4.2 Functional block diagram

As depicted in Figure 65–5, the FEC sublayer comprises a transmit side and a receive side. The following sections define the functionality of each block in the sublayer.

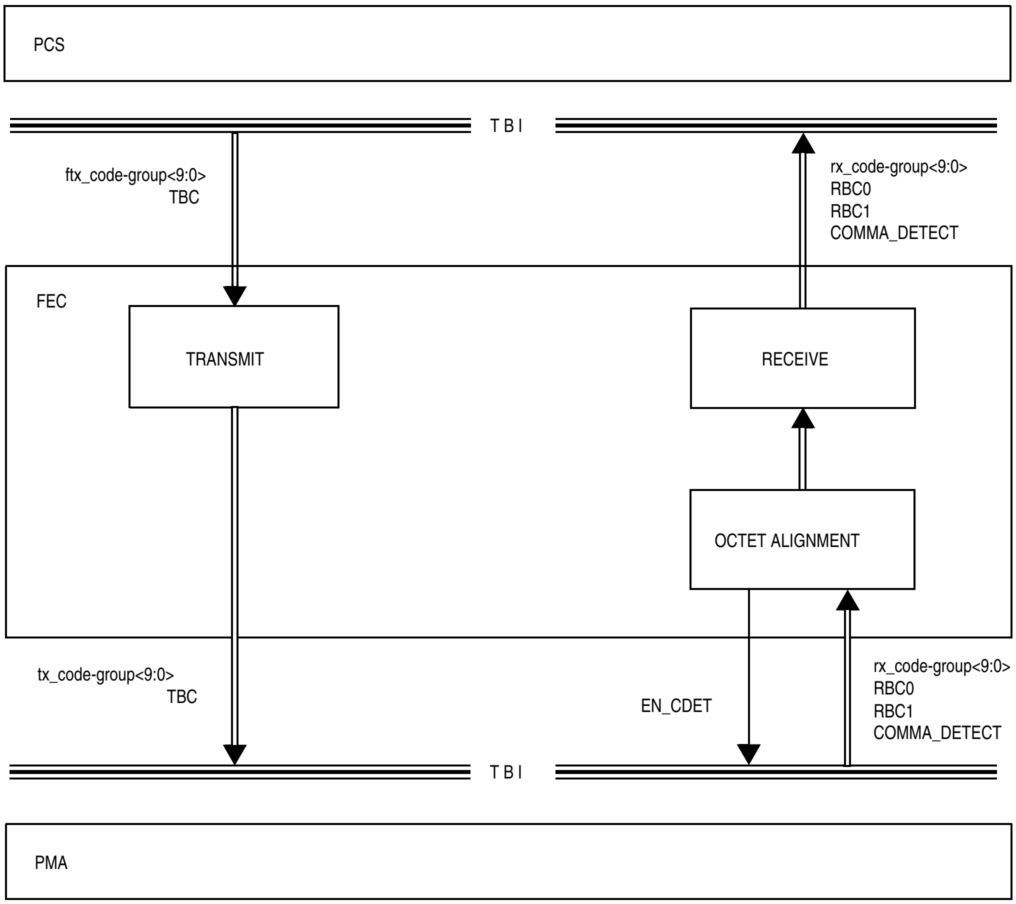


Figure 65–5—Functional block diagram

65.2.4.2.1 Transmission

Figure 65–6 descibes a block diagram of the FEC sublayer transmit data path. The packet delimiters of the packets from the PCS are detected. The /I/I/S/ is replaced with the /S_FEC/ ordered_set. The data in the frame is then 8B/10B decoded so that the FEC coding can take place and the parity octets buffered The /T/R/ or /T/R/R/ is detected and replaced with the /T_FEC_E/ or /T_FEC_O/, respectively. Then the parity octets and another /T_FEC_E/ is appended.

The FEC Transmit process continuously generates code-groups based upon information provided in the PMA_UNITDATA.request primitive with the tx_code-group<9:0> parameter, sending them immediately to the PMA Service Interface via the same primitive with the ftx_code-group<9:0> parameter.

65.2.4.2.2 Reception

Figure 65–7 describes the receive octet alignment block diagram of the FEC sublayer receive data path. The unaligned data from the PMA is shifted into a 20-bit buffer. The buffer is searched for the comma sequence, as described in *CROSS REF* 36.2.4.9. When a comma is detected then the state machine searches further for

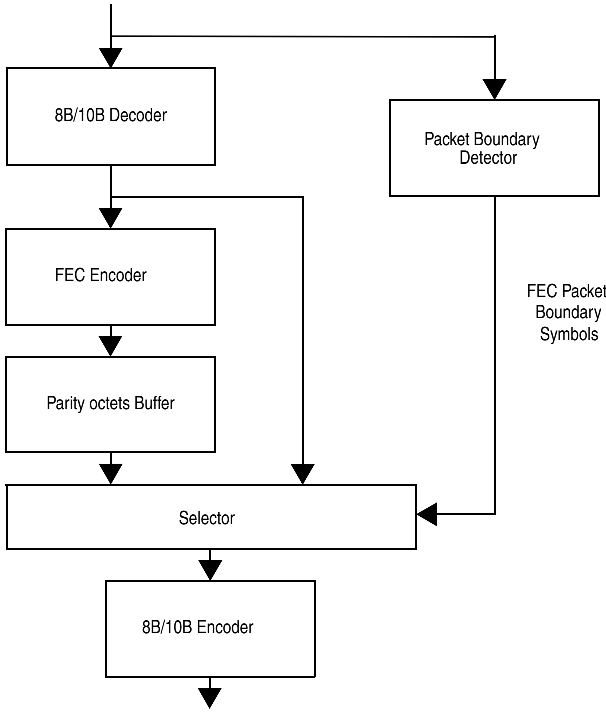


Figure 65–6—Transmit block diagram

6 consecutive /I/ ordered_sets. Upon detection, the alignment mux is configured. The output of the alignment mux is searched for K consecutive invalid code-groups. When this occurs, the alignment machine is reset.

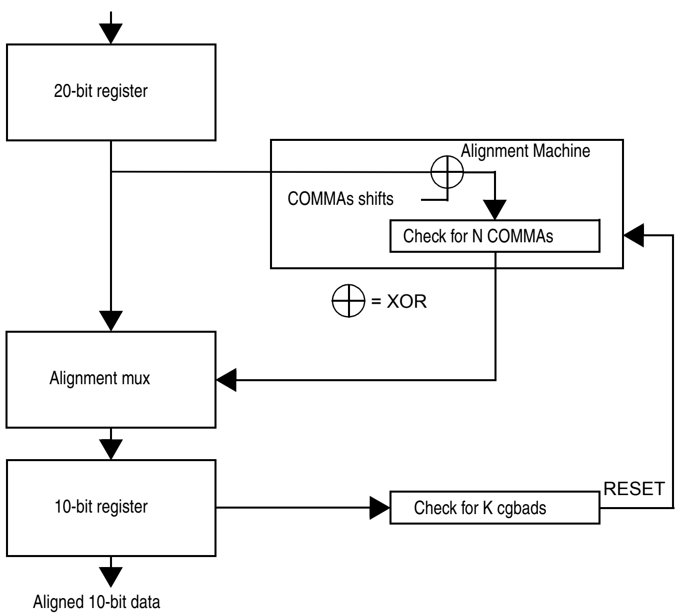


Figure 65–7—Receive octet alignment block diagram

Figure 65–8 describes a block diagram of the FEC sublayer receive data path. A buffer exists in order to receive the maximum length packet, the delimiters and the first 16 parity octets so that data correction can take place before data is passed to the PCS. When an /S_FEC/ is detected, the packet is stored in the buffer. As the parity octets arrive, error correction takes place and data is passed through to the PCS. Packets that are not FEC encoded are subject to the constant delay of the buffer but do not participate in any error correction.

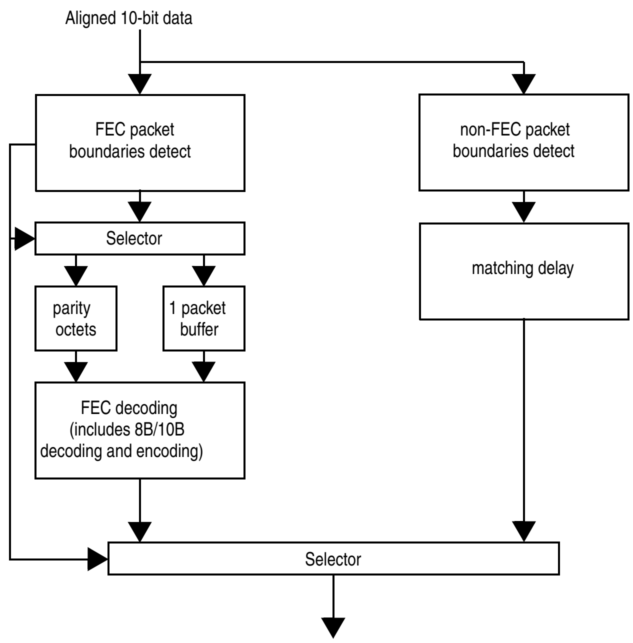


Figure 65–8—Receive data block diagram

65.2.4.3 State diagrams

65.2.4.3.1 Constants

See *CROSS REF* 36.2.5.1.2.

65.2.4.3.2 Variables

See *CROSS REF* 36.2.5.1.3, replacing “PCS” with “FEC sublayer”.

> ***Editors note:*** *To be removed prior to final publication*
>
> I don’t know if this is a legal reference but it works for now. These sections can all be duplicated if necessary. Also, there are many variable and function definitions missing.

buffer_head
: The code-group at the head of the Receive process buffer.

fec_encode
: A boolean set by the FEC Transmit process to indicate the status of the RS_Encode(Data) function.

Values:

TRUE; data is acted upon by the RS_Encode(Data) function.

FALSE; data is not being acted upon by the RS_Encode(Data) function.

ftx_bit

A binary parameter used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in *CROSS REF* 58.1.4.1.

Values:
ZERO;Data bit is a logical zero.
ONE;Data bit is a logical one.

ftx_code-group<9:0>

A vector of bits representing one code-group, as specified in Tables 36–1a through 36–2, which has been prepared for transmission by the FEC Transmit process. This vector is conveyed to the PMA as the parameter of a PMA_UNITDATA.request(ftx_code-group) service primitive. The element ftx_code-group<0> is the first ftx_bit transmitted; ftx_code-group<9> is the last ftx_bit transmitted.

parity<D7:D0>

An 8-bit array that contains the current parity bits to be encoded in the FEC Transmit Process. The elements within the array are updated with the next 8-bits to be encoded upon each entry into the XMIT_PARITY state.

For each element within the array: Values:
ZERO;Data bit is a logical zero.
ONE;Data bit is a logical one

parity_buffer_empty

A boolean set by the FEC Transmit process to indicate if more parity bytes need to be encoded.

Values:
TRUE;No more parity bytes need to be encoded.
FALSE;More parity bytes need to be encoded.

rx_disparity

A boolean set by the FEC Receive process to indicate the running disparity at the end of code-group reception as a binary value. Running disparity is descibed in *CROSS REF* 36.2.4.3.

Values:
POSITIVE
NEGATIVE

65.2.4.3.3 Functions

See *CROSS REF* 36.2.5.1.4, replacing “PCS” with “FEC sublayer”.

check_ahead_tx

Prescient function used by the FEC Transmit process to find the Start_of_Packet in order to replace the Start_of_Packet and its two preceding IDLE ordered_sets with /S_FEC/.

check_ahead_rx

Prescient function used by the FEC Receive process to find the /S_FEC/ and /T_FEC/, with fewer than d/2 errors.

POP_BUFFER

Removes the octet at the head of the Receive process buffer, making the next octet available.

RS_Encode(Data)

This function is used to encode the Reed Solomon (255,239) code. The encoder encodes the 239 octets data frame and generates 16 parity bytes for each data frame. Before being passed to the Reed Solomon encoder, this function passes the data through DECODE([/x/]).

RS_Decode(Data)
: This function is used to decode the Reed Solomon (255,239) code. The decoder decodes the 255 symbols data frame and generates 239 corrected data octets for each frame and an error signal.

Save[Data]
: This function is used to store the input data.

Delay[Data,T]
: This function is used to delay the input data for T octets.

65.2.4.3.4 Counters

See *CROSS REF* 36.2.5.1.5.

loop_count
: A 3-bit counter used to keep track of the number of loops in the receive byte alignment process.

65.2.4.3.5 Messages

See *CROSS REF* 36.2.5.1.6, replacing “PCS” with “FEC sublayer”.

65.2.4.3.6 Timers

See *CROSS REF* 36.2.5.1.7.

65.2.4.3.7 Transmit state diagram

Figure 65–9 shows the transmit state diagram

65.2.4.3.8 Receive octet alignment state diagram

Figure 65–10 shows the receive octet alignment state diagram.

65.2.4.3.9 Receive state diagram

Figure 65–12 shows the first part of the receive state diagram, the one that fills the buffer. Figure 65–12 shows the second part, the one that empties it.

The buffer_fill process uses the check_ahead function to find an /S_FEC/ with fewer than d/2 bit errors and replaces it with /I/I/S/. While waiting until a /T_FEC/ arrives, the buffer is filled with the all received octets. When the check_ahead function finds a /T_FEC/ with fewer than d/2 errors, it is replaced with a non-errored /T_FEC/. The latter portion of the first /T_FEC/, all the parity octets and the final /T_FEC/ is replaced with / I/ by the buffer_empty process.

The buffer_empty process searchs the head of the buffer for /S/ then for /T/ then for /I/, all the while, sending the octet at the head of the buffer to the PCS. If the next code-group is /T/ then the process replaces octets at the head of the buffer with /I/ until at least 2 /I/ are detected. This results in discarding all parity octets, should they exist.

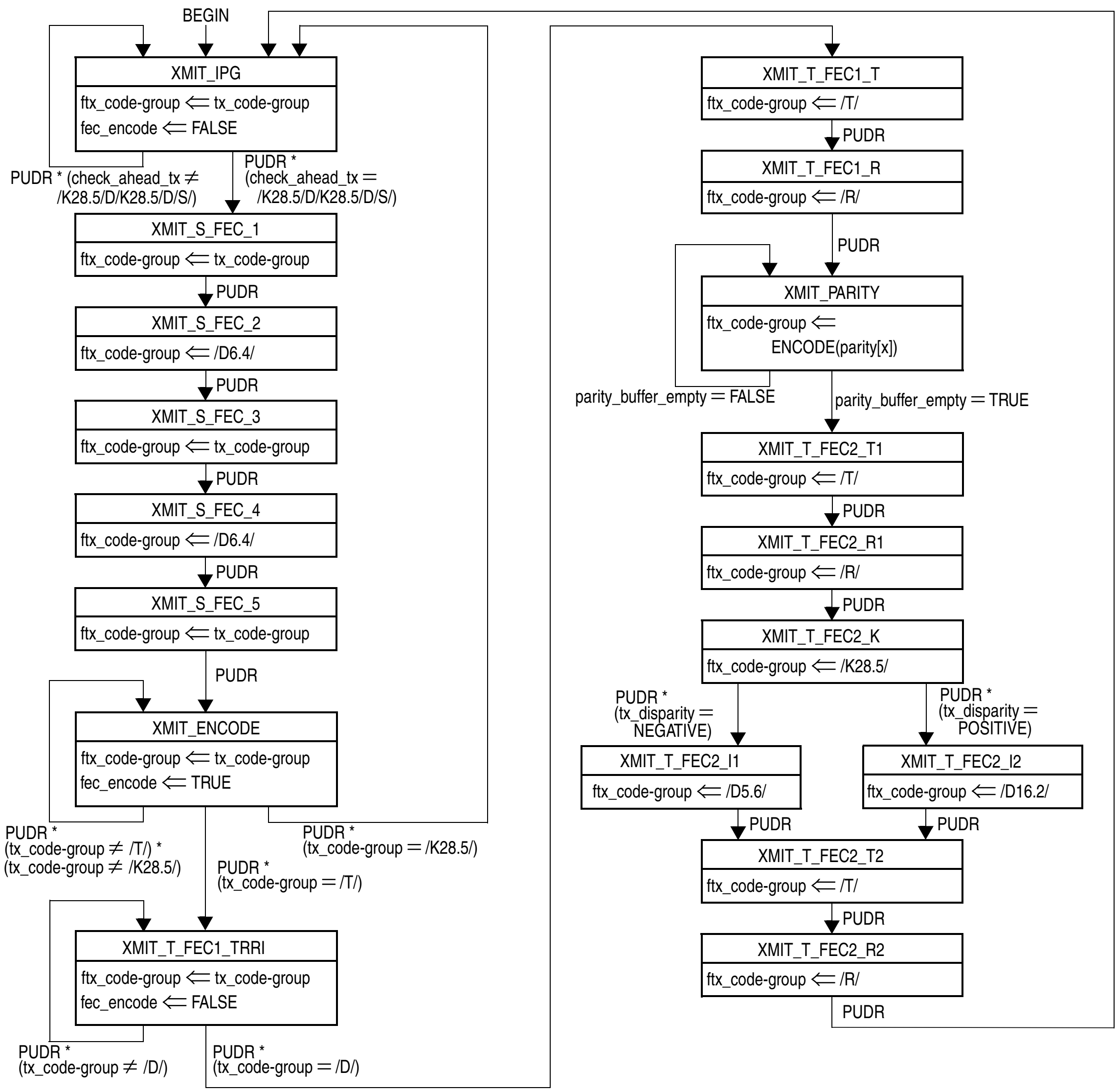


Figure 65–9—Transmit state diagram

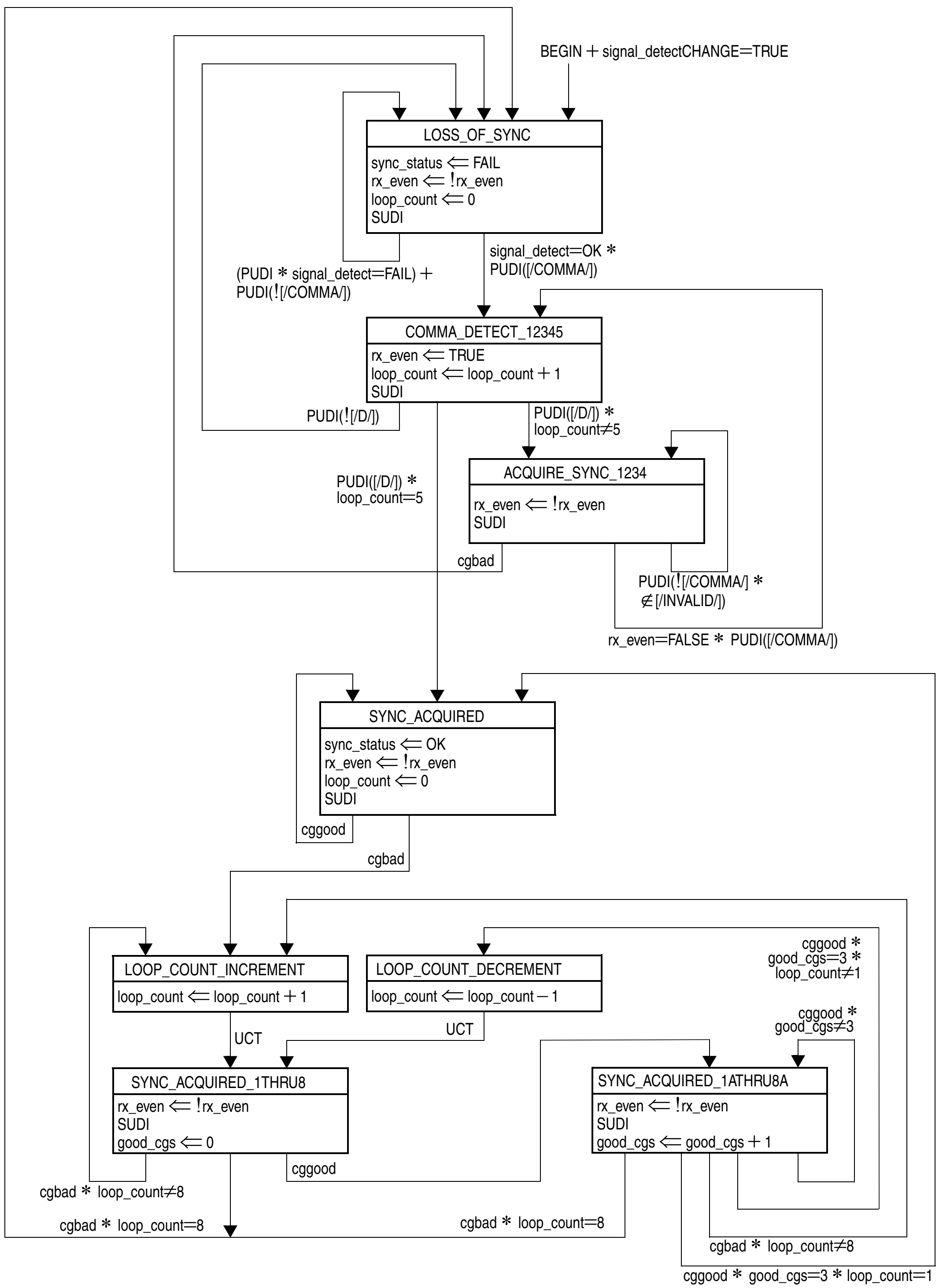


Figure 65–10—Receive byte alignment state diagram

It is expected that the FEC decoding is performed while the data is in the buffer.

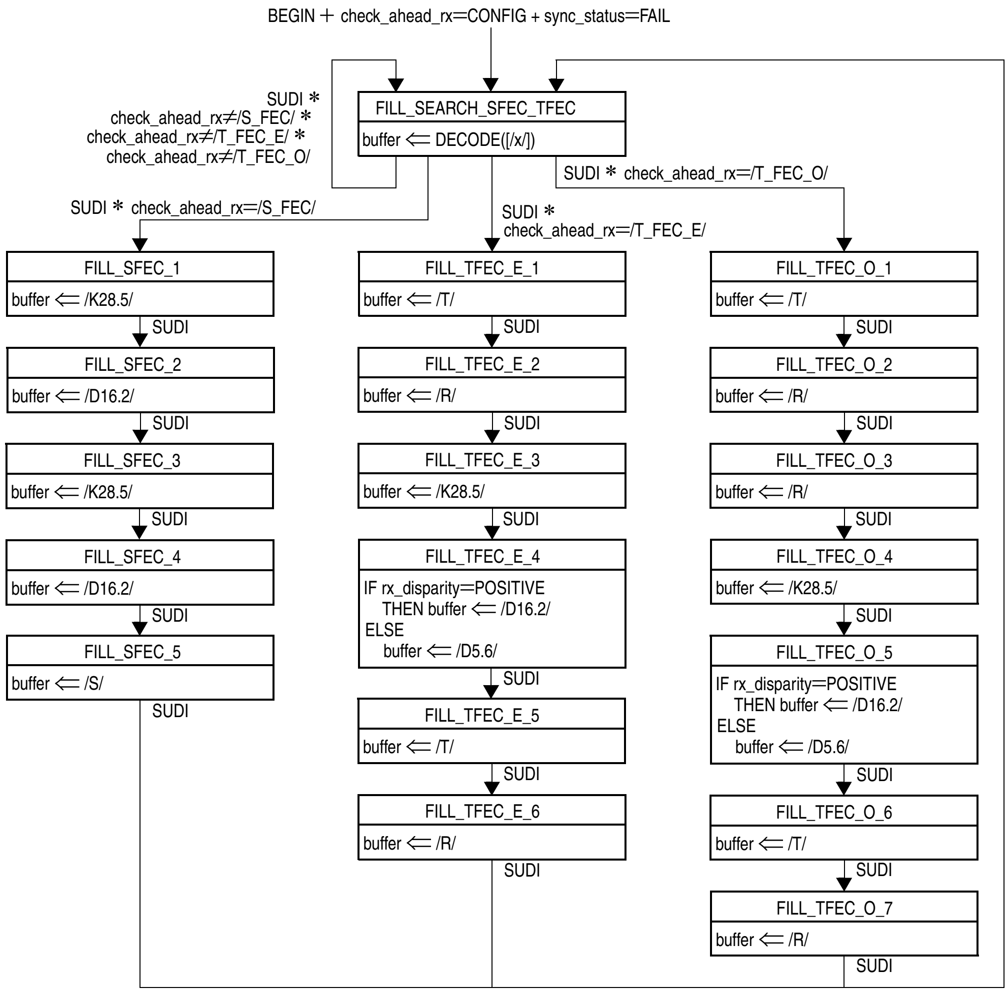


Figure 65–11—Receive buffer-fill state diagram

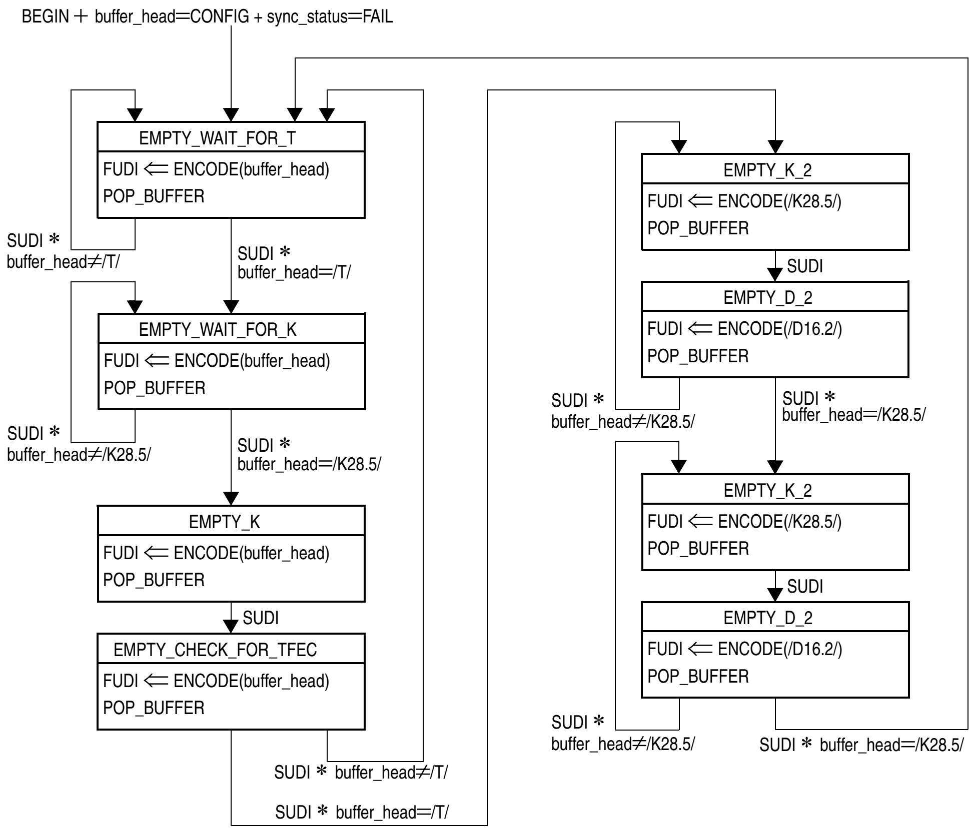


Figure 65–12—Receive buffer-empty state diagram

65.2.4.4 Error monitoring capability

> ***Editors note:*** *To be removed prior to final publication*
>
> There was no text in the Word document for this section. The editor humbly requests complete submissions for the text under this heading.

65.3 Extension to PMA receive clock requirement for 1000BASE-PX OLT

In addition to the requirements defined in clause 36, P2MP operation imposes the following requirement on the PMA attachment sublayer of the OLT.

65.3.1 Burst Mode Specifications for receive clock acquisition time

In the presence of the received data pattern as described in (See *CROSS REF* 64.x.y.z), COM_DET shall assert in less than 500 bit times when PMA_TX_CLK frequency is equal to twice the PMA_RX_CLK frequency.

65.3.2 Burst Mode Comma Detect

Item	Feature	Subclause	Value/Comment	Status	Support
BMC1	Code-group alignment	65.3.1	In the presence of the received data pattern specified in *CROSS REF* 64.x.y.z	M	Yes[]

Editors note: *To be removed prior to final publication*

This specification is based on a motion from the Vancouver interim initially presented at the joint Optics-P2MP STF and then to the AH TF. More details forthcoming.

66. System considerations for Ethernet subscriber access networks

Editors' Notes: To be removed prior to final publication.

References:

None.

Definitions: (to be added to 1.4):

None.

Abbreviations (to be added to 1.5):

None.

Revision History:

Draft 1.3 January 2003 Initial Draft for IEEE 802.3ah Task Force review.
Draft 1.414 April 2003 Draft for IEEE 802.3ah Task Force review, incorporating comments received at March, 2003 meeting in Dallas, Texas.

66.1 Overview

This clause provides information on building Ethernet subscriber access networks, also referred to as “Ethernet in the First Mile”, or EFM networks.

EFM encompasses a family of technologies that vary in media type and signalling speed. EFM is designed to be deployed in networks of one or multiple EFM media type(s) as well as interact with mixed 10/100/1000/10000 Mb/s Ethernet networks. Any network topology defined in IEEE Std 802.3 can be used within the subscriber premises and then connected to an Ethernet subscriber access network via an IEEE Std 802.1D compliant bridge, or a router.

Further, within a given EFM domain, the specific EFM technologies allow for a variety of topologies affording the subscriber access network maximum flexibility. For example, a 1000BASE-PX10 P2MP system with 16 ONUs can be built with a 1:16 splitter or as a tree-and-branch network utilizing more than one splitter.

The design of multiple-domain networks is governed by the rules defining each of the transmission systems incorporated into the design. The physical size of a network is limited by the characteristics of individual network components. These characteristics include the media lengths and type.

Table 66–1 summarizes the various EFM media characteristics.

Table 66–1—Characteristics of the various EFM network media segments

Media type	Rate (Mb/s)	Number of PHYs segment	Nominal span (km)
Optical 100 Mb/s Fiber Segment (100BASE-LX10, 100BASE-BX10)	**100**	**2**	**10**
Optical 1000 Mb/s Fiber Segment (1000BASE-LX10, 1000BASE-BX10)	**1000**	**2**	**10**
Optical 1000 Mb/s P2MP Segment (1000BASE-PX10)	**1000**	**17**[a b]	**10**
Optical 1000 Mb/s P2MP Segment (1000BASE-PX20)	**1000**	**17**[a b]	**20**
Copper High Speed Segment (10PASS-TS)	**10**[c]	**2**	**varies**[d]
Copper Long Reach Segment (2BASE-TL)	**2**[c]	**2**	**varies**[e]

[a]P2MP segments may be implemented with a trade off trade off between link span and split ratio listed. Refer to 66.2.1.
[b]The number of PHYs in the P2MP segment includes the OLT PHY.
[c]Nominal
[d]0.75km (nominal)
[e]2.7km (nominal)

66.2 Discussion and Examples of EFM P2MP topologies

This section discusses EFM P2MP topologies. It details flexibility of trading off split ratio for link span. This section also shows some examples of different P2MP topologies.

66.2.1 Trade off between link span and split ratio

66.2.2 Single splitter topology

66.2.3 Tree-and-branch topology

66.2.4 Serial topology

66.3 Hybrid Media topologies

66.4 Full duplex 2, 10, 100 and 1000 Mb/s topology limitations

The physical size of full duplex EFM networks is not limited by the round-trip collision propagation delay. Instead, the maximum link length between DTEs is limited only by the signal transmission characteristics of the specific link.

66.5 Deployment restrictions for subscriber access copper

10PASS-TS and 2BASE-TL PHYs have been specified to allow deployment on public access networks, however many local regulations apply to such networks. It is important that systems are designed and configured to comply with all appropriate regulatory, governmental and regional requirements. Refer to Annex 62A (10PASS-TS) and Annex 63A (2PASS-TL) for further information regarding configuration profiles.

66.6 Operations, Administration and Maintenance

All P2P and emulated P2P links, including all of the EFM network media segments, support the optional OAM sublayer as defined in Clause 57.

66.6.1 Unidirectional links

Prior to EFM, compliant 100 Mb/s, 1000 Mb/s and 10 Gb/s PCS implementations are not capable to encoding and transmitting data while one direction of the link is nonoperational. Some newer physical layer devices support the optional ability to encode and transmit data while one direction of the link is non-operational. This capability is indicated by the management register bit 1.7

Unidirectional OAM Ability found in Table 22-8. This feature is enabled via the management register bit 0.1 Unidirectional OAM Enable found in Table 22-7. This bit should only be set when the OAM sublayer is present and enabled. Otherwise, MAC Client frames will be sent across a unidirectional link potentially causing havoc with bridge and other higher layer protocols.

66.6.2 Active and Passive modes

A device may be configured to be in either Active or Passive OAM mode. One end of a given link is required to be in Active mode.

In an access network, customer premises devices will commonly be configured as Passive devices. All other devices in an access network will commonly be configured as Active devices. For a detailed description of Active and Passive mode, refer to 57.2.6.

Changes to ANSI/IEEE Std 802.3, 2002, Annex 31A

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: *To be removed prior to final publication.*

References:
None.

Definitions:
None.

Abbreviations:
None.

Changes:

Revision History:

Draft 1.414, April 2003	Initial draft of changes.

Annex 31A

(normative)

MAC Control opcode assignments

Table 31A–1 shows the currently defined opcode values and interpretations:

Table 31A–1—MAC Control opcodes

Opcode (Hexadecimal)	MAC Control function	Specified in ~~Annex~~	Value/comment
00-00	Reserved		
00-01	PAUSE	Annex 31B	Requests that the recipient stop transmitting non-control frames for a period of time indicated by the parameters of this function.
00-02	GATE	64	Request that the recepient allow transmission of frames at a time, and for a period of time indicated by the parameters of this function.
00-03	REPORT	64	Notify the recepient of pending transmission requests as indicated by the parameters of this function.
00-04	REGISTER_REQ	64	Request that the station be recognized by the protocol as participating in a gated transmission procedure as indicated by the parameters of this function.
00-05	REGISTER	64	Notify the recepient that the station is recognized by the protocol as participating in a gated transmission procedure as indicated by the parameters of this function.
00-06	REGISTER_ACK	64	Notify the recepient that the station acknowledges participation in a gated transmission procedure.
00-0~~2~~7 through FF-FF	Reserved		

Opcodes are transmitted high-order octet first. Within each octet, bits are transmitted least-significant bit first. Reserved opcodes shall not be used by MAC Control sublayer entities.

The following tables ~~Table 31A–3~~ shows~~s~~ the elements and semantics of the indication_operand_list for MA_CONTROL.indication primitives for each currently defined opcode value in Table 31A–1::

Table 31A–2—PAUSE MAC Control indications

PAUSE (opcode 0x0001)		
indication_operand_list element	**Value**	**Interpretation**
pause_status	paused	Indicates that the PAUSE function is inhibiting transmission of data frames by the MAC client.
	not_paused	Indicates that the PAUSE function is not inhibiting transmission of data frames by the MAC client.

Table 31A–3—GATE MAC Control indications

GATE (opcode 0x0002)		
indication_operand_list element	**Value**	**Interpretation**
start	32 bit	Time where GATE function should activate
length	32 bit	Length of time where GATE function should be active for.
status	arrive	Indicates that a GATE was received for future activation.
	active	Indicates that the GATE function is allowing transmission of frames.
	deactive	Indicates that the GATE function is inhibiting transmission of frames.
force_report	true	The OLT expects the ONU to generate a REPORT at the next tranmission opportunity folowing this indication.
	false	The OLT does not request the ONU to generate a REPORT at the next tranmission opportunity folowing this indication.

Table 31A–4—REPORT MAC Control indications

REPORT (opcode 0x0003)		
indication_operand_list element	**Value**	**Interpretation**
RTT	32 bit	Indicates the calculated round trip time for the station, as calculated following the REPORT message reception.
n	Integer	Indicates the number of queue status reports present
report_list	valid[8]	Indicates whether the corresponding status element is present when set to true.
	status[8]	Indicates amount of pending transmission in the corresponding queue.

Table 31A–5—REGISTER_REQ MAC Control indications

REGISTER_REQ (opcode 0x0004)		
indication_operand_list element	**Value**	**Interpretation**
status	incoming	Indicates that a station is requesting recognition.
	retry	Indicates that the station should reattempt registration.
flags	register	Indicates that the station is requesting to register.
	deregister	Indicates that the station is requesting to deregister.
pending_grants	Integer	Indicates the maximal number of future GATES that can be stored by the GATE function.
RTT	32 bit	Indicates the calculated round trip time for the station, as calculated following the REGISTER_REQ message reception.

Table 31A–6—REGISTER_ACK MAC Control indications

REGISTER_ACK (opcode 0x0006)		
indication_operand_list element	**Value**	**Interpretation**
ID	16 bit	Indicates the LLID allocated to the ONU.
status	accepted	Indicates the station has been recognized as participating in gated transmission.
	denied	Indicates the station has been excluded from participating in gated transmission.
	reset	Indicates the station has been requested to resubmit a registration request.
	deregistered	Indicates that the station will no longer be participating in gated transmission.
RTT	32 bit	Indicates the calculated round trip time for the station, as calculated following the REGISTER_ACK message reception.

Changes to ANSI/IEEE Std 802.3, 2002, Annex 43B

EDITORIAL NOTES - This amendment is based on the current edition of IEEE Std 802.3, 2002. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of P802.3ah.

Editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Editorial notes will not be carried over into future editions.

Editors' Notes: *To be removed prior to final publication.*

References:
None.

Definitions:
None.

Abbreviations:
None.

Changes:
a) Restriction on number of frames transmitted per second increased from 5 to 10.
b) OAM subtype added to list of Slow Protocols.

Revision History:

Draft 1.0, August 2002	Initial draft for IEEE P802.3ah Task Force review.
Draft 1.1, October 2002	Reduce content of file to changes only.
Draft 1.2, November 2002	No changes.
Draft 1.3, January 2003	Changed reference to OAM clause (now 57).
Draft 1.414, April 2003	No changes other than draft number and date.

Annex 43B Requirements for support of Slow Protocols

43B.2 Slow Protocol transmission characteristics

Change the following section to read as follows:

Protocols that make use of the addressing and protocol identification mechanisms identified in this annex are subject to the following constraints:

a) No more than ~~5~~ 10 frames shall be transmitted in any one-second period.

b) The maximum number of Slow Protocols is 10.

NOTE—This is the maximum number of Slow Protocols that use the specified protocol type defined here. That is, there may be more than 10 slow protocols in the universe, but no more than 10 may map to the same Ethernet Length/Type field.

c) The MAC Client data generated by any of these protocols shall be in the normal length range for an IEEE 802.3 MAC frame, as specified in 4.4.2. It is recommended that the maximum length for a Slow Protocol frame be limited to 128 octets.

NOTE—The Slow Protocols specified in Clause 43 (i.e., LACP and Marker) conform to this recommended maximum. The OAM protocol specified in CROSS REF Clause 57 may generate frames greater than 128 octets.

d) PDUs generated by these protocols shall use the Basic and not the Tagged frame format (see Clause 3).

The effect of these restrictions is to restrict the bandwidth consumed and performance demanded by this set of protocols; the absolute maximum traffic loading that would result is ~~50~~ 100 maximum length frames per second per point-to-point link and 100 maximum length frames per ONU for point-to-multipoint link.

43B.4 Protocol identification

Change one row of the following table to read as follows:

Table 43B–3—Slow Protocols subtypes

Protocol Subtype value	Protocol name
3	~~Reserved for future use~~ Operations, Administration and Maintenance (OAM)

Annex 45B

(informative)

Clause 22 access to Clause 45 MMD registers

Editors' Notes: To be removed prior to final publication.

References:

None.

Definitions (to be added to 1.4):

None

Abbreviations (to be added to 1.5):

None

Revision History:

Draft 1.2	November 2002	Added draft as a result of IEEE P802.3ah Task Force review in Kauai.
Draft 1.3	January 2003	Draft for Task Force review. Incorporates the changes from the January Interim meeting in Vancouver.
Draft 1.414	April 2003	No changes as a result of IEEE P802.3ah Task Force review in Dallas other than updating the draft number and date.

Clause 22 provides access to Clause 45 registers using registers 13 and 14. This informative annex provides users with some insight regarding how these accesses are intended to work. Accesses to registers 13 and 14, for the purpose of accessing registers in a Clause 45 MMD, should be performed atomically to avoid the chance of another process changing the Function, DEVAD or Address fields within the MMD. This is the same requirement of Clause 45 accesses.

45B.1 Write operation

To write a Clause 45 register using the Clause 22 access mechanism, perform the following accesses using the appropriate PHY Address for the PHY of interest:

a) To register 13, write the Function field to 00 (Address) and DEVAD field to the Device Address value for the desired MMD;
b) To register 14, write the desired address value to the MMD's address register;
c) To register 13, write the Function field to 01 (Data, no post increment) and DEVAD field to the same Device Address value for the desired MMD;
d) To register 14, write the content of the MMD's selected register.

45B.2 Read operation

To read a Clause 45 register using the Clause 22 access mechanism, perform the following accesses using the appropriate PHY Address for the PHY of interest:

a) To register 13, write the Function field to 00 (Address) and DEVAD field to the Device Address value for the desired MMD;
b) To register 14, write the desired Address value to the MMD's address register;
c) To register 13, write the Function field to 01 (Data, no post increment) and DEVAD field to the same Device Address value for the desired MMD;
d) From register 14, read the content of the MMD's selected register.

45B.3 MMD Address operations

45B.3.1 Address

While the Function field contains the value 00 (Address):

a) subsequent writes to register 14 continue to rewrite MMD DEVAD's address register;
b) subsequent reads from register 14 continue to reread MMD DEVAD's address register.

45B.3.2 Data, no post increment

While the Function field contains the value 01 (Data, no post increment):

a) subsequent writes to register 14 continue to rewrite the data register selected by the value in MMD DEVAD's address register;
b) subsequent reads from register 14 continue to reread the data register selected by the value in MMD DEVAD's address register.

45B.3.3 Data, post increment on reads and writes

While the Function field contains the value 10 (Data, post increment on reads and writes):

a) subsequent writes to register 14 write the next higher addressed data register selected by the value in MMD DEVAD’s address register, i.e. MMD DEVAD’s address register is post incremented after each access;

b) subsequent reads from register 14 read the next higher addressed data register selected by the value in MMD DEVAD’s address register, i.e. MMD DEVAD’s address register is post incremented after each access.

45B.3.4 Data, post increment on writes only

While the Function field contains the value 11 (Data, post increment on writes only):

a) subsequent writes to register 14 write the next higher addressed data register selected by the value in MMD DEVAD’s address register, i.e. MMD DEVAD’s address register is post incremented after each access;

b) subsequent reads from register 14 continue to reread the data register selected by the value in MMD DEVAD’s address register.

This Function enables a read-modify-write capability for successively addressed registers within a MMD.

45B.4 PHY Coexistence and bus conflict avoidance

There are multiple levels of coexistence on the MDIO bus:

a) PHYs accessible via the Clause 22 access mechanism can coexist on the same bus using different PHY Address values;

b) PHYs accessible via the Clause 45 access mechanism can coexist on the same bus using different PHY Address values;

c) PHYs accessible via the Clause 22 access mechanism can coexist on the same bus with PHYs accessible via the Clause 45 access mechanism, even with identical PHY Address values due to the different ST (start of frame) encodings of the frame structures;

d) MMDs with the same PHY Address, regardless of their access mechanisms, can coexist on the same bus using different Device Address values.

Coexistence of MMDs with the same PHY Address is worth more consideration. MMDs using the Clause 45 access mechanism and sharing a common PHY address avoid bus conflicts because Device Address is part of the frame structure. Only an MMD with a matching Device Address responds to the bus access. MMDs using the Clause 22 access mechanism and sharing a common PHY address avoid bus conflicts using Device Address as well. However, the Device Address is available from the contents of the MMD’s register 13.

These MMDs avoid bus conflicts by following these simple rules:

1) All MMDs respond to writes to register 13. They all have a copy of register 13 and all copies contain the same value;

2) Only the MMD with a device address matching the value in the DEVAD field in its copy of register 13 responds to a read of register 13 or any access to register 14.

Annex 61A

(informative)

EFM Copper Examples

Editors' Notes: *To be removed prior to final publication.*

Normative References:

Informative References:

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):

Revision History:
The content of this Annex was part of Clause 45 until Draft 1.3.
Draft 1.414 April 2003 Draft for IEEE P802.3ah Task Force review

61A.1 Purpose and scope

The purpose of this informative annex is to provide practical examples of the use of Clause 45 registers with respect to the operation of 10PASS-TS PHYs (Clause 62) and 2BASE-TL PHYs (Clause 63).

61A.2 Aggregation Discovery Example

An example procedure for PMI aggregation discovery is described for system components as shown in Figure 61A–1, connected as in Figure 61A–2.

An example procedure for discovering this connectivity follows:

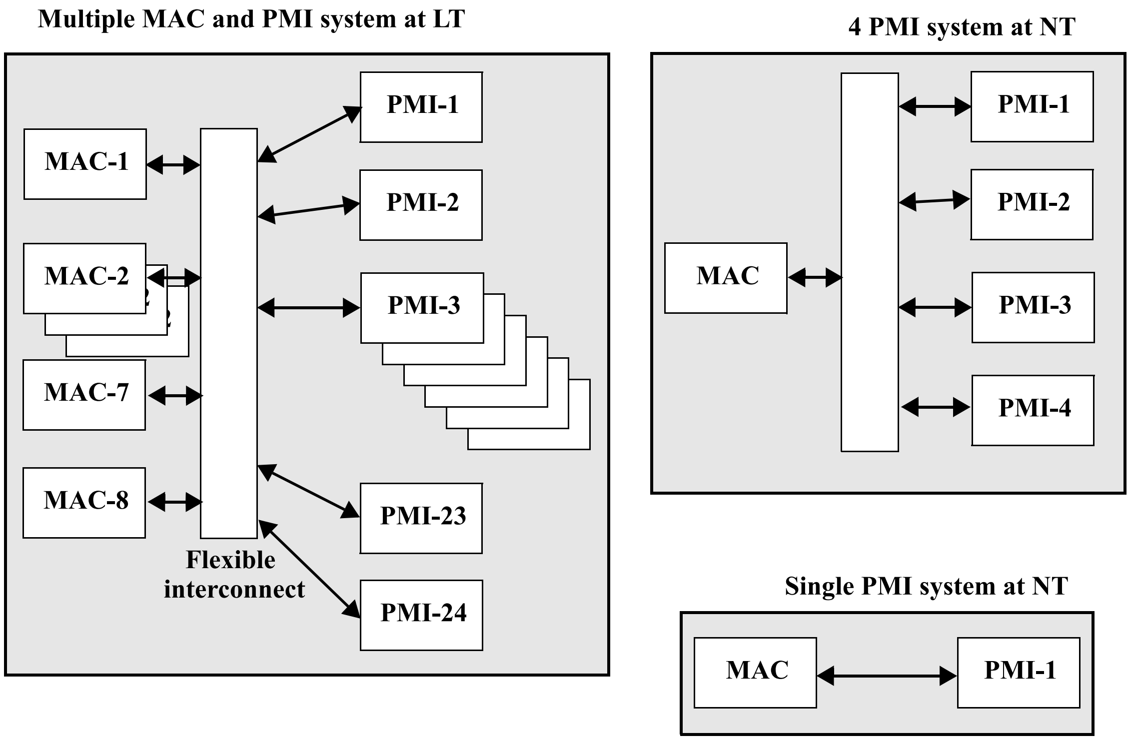


Figure 61A–1—Example systems for discovery

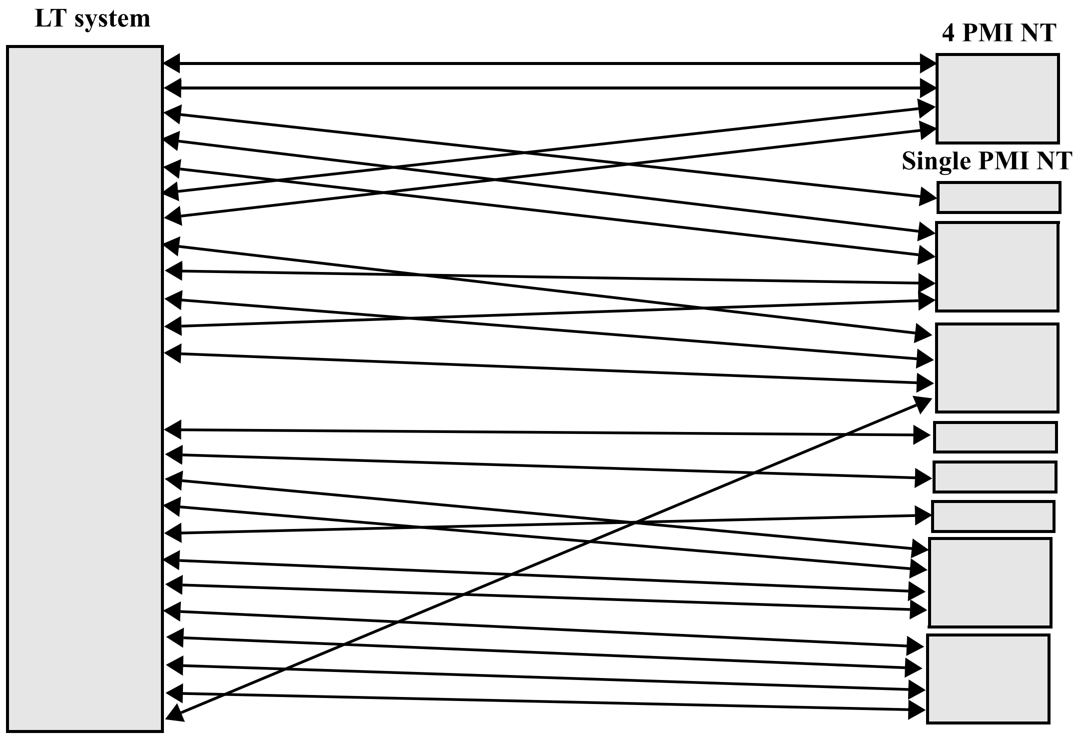


Figure 61A–2—System connectivity for discovery example

a) LT system writes remote PMI_Discovery_Register to value *alpha* (*alpha* may be any 48 bit value, but would benefit from being locally unique e.g. MAC address) using PMI-1.
b) LT system reads remote PMI_Discovery_Register for all other PMIs.
c) LT system discovers that PMI-2, PMI-6 and PMI-7 are associated with the same remote MAC device as PMI-1.
d) LT system writes remote PMI_Discovery_Register to value *alpha* using PMI-3 - the next non-associated PMI.
e) LT system reads remote PMI_Discovery_Register for all other PMIs.
f) LT system expects that PMI-1, PMI-2, PMI-3, PMI-6 and PMI-7 will already be written to value *alpha*.
g) LT system discovers that no other PMI is associated with the same remote MAC device as PMI-3.
h) LT system writes remote PMI_Discovery_Register to value *alpha* using PMI-4 - the next non-associated PMI.
i) LT system reads remote PMI_Discovery_Register for all other PMIs.
j) LT system expects that PMI-1, PMI-2, PMI-3, PMI-4, PMI-6 and PMI-7 will already be written to value *alpha*.
k) LT system discovers that PMI-5, PMI-9 and PMI-11 are associated with the same remote MAC device as PMI-4.
l) This procedure repeats for all of the PMIs connected to LT system.

An alternate example procedure for discovering this connectivity uses two different 48 bit values:

a) LT system writes remote PMI_Discovery_Register to value *alpha* (*alpha* may be any 48 bit value, but would benefit from being locally unique e.g. MAC address) using PMI-1.
b) LT system reads remote PMI_Discovery_Register for all other PMIs.
c) LT system discovers that PMI-2, PMI-6 and PMI-7 are associated with the same remote MAC device as PMI-1.

d) LT system rewrites remote PMI_Discovery_Register to value *beta* (*beta* may be any 48 bit value, different to *alpha*) using PMI-1.
e) LT system writes remote PMI_Discovery_Register to value *alpha* using PMI-3 - the next non-associated PMI.
f) LT system reads remote PMI_Discovery_Register for all other PMIs.
g) LT system discovers that no other PMI is associated with the same remote MAC device as PMI-3.
h) LT system rewrites remote PMI_Discovery_Register to value *beta* using PMI-3.
i) LT system writes remote PMI_Discovery_Register to value *alpha* using PMI-4 - the next non-associated PMI.
j) LT system reads remote PMI_Discovery_Register for all other PMIs.
k) LT system discovers that PMI-5, PMI-9 and PMI-11 are associated with the same remote MAC device as PMI-4.
l) LT system rewrites remote PMI_Discovery_Register to value *beta* using PMI-4.
m) This procedure repeats for all of the PMIs connected to LT system.

Note also that a large and complex LT system may perform multiple discovery operations in parallel by using multiple unique 48 bit values for writing the remote PMI_Discovery_Register.

Annex 62A

(normative)

PMD Profiles for 10PASS-TS

Editors' Notes:

References:

ITU-T Recommendation G.993.1.
ETSI TS1 101 270-1
T1.424/Trial-Use

Definitions (to be added to 1.4):

bandplan: *the set of parameters that defines the start and end of each 10PASS-TS frequency band.*

Abbreviations (to be added to 1.5):

Revision History:

Draft 1.1 October 2002 Preliminary draft for IEEE P802.3ah Task Force review
Draft 1.2 November 2002 Preliminary draft for IEEE P802.3ah Task Force review
Draft 1.3 February 2003 Preliminary draft for IEEE P802.3ah Task Froce review
Draft 1.414 April 2003: Preliminary draft for IEEE P802.3ah Task Force Review

Editor's Note: Comment #63006/D1.3, unanimously accepted by the Copper Sub Task Force, required the removal of 62A.3.3.5 "Bandplan parametrization". Comment #490/D1.3, accepted in principle by the Copper Sub Task Force, required the addition on specific references to standardized band plans. To facilitate the implementation of these comments, the Editor has modified the structure of this Annex, and made several editorial modifications to the text.

62A.1 Introduction and rationale

Annex 62A defines the PMD profiles for 10PASS-TS. These profiles define the transmission characteristics of the PHY on the media. 10PASS-TS PHYs are required to operate across varying media quality, regulatory and noise environments.

The profiles defined in this clause have two purposes. The first is to describe a bounded set of operating modes that a party might choose from when implementing, integrating and installing 10PASS-TS equipment. 10PASS-TS PHYs are inherently flexible in their transmission capabilities. The possible combination of transmission parameters are nearly infinite. The defined profiles collect a small subset of these parameters into modes that work well in most deployments. For deployments that require an operating mode not defined in this Annex, profiles can be overridden by setting PHY PMD registers directly, via Clause 45 for example. Informative Annex 62C contains examples of such user-defined modes of operation.

The second purpose of profiles is to define a set of operating modes against which PHY performance compliance may be tested. The topic of performance compliance is addressed for 10PASS-TS in Annex 62B.

62A.2 Relationship to other clauses

Clause 30 [see Clause 30] describes how the selection of Annex 62A profiles is exported to a management entity.

Clause 45 registers describe an optional mechanism for configuring a 10PASS-TS PHY to use a particular profile. The register settings for each profile are contained in 62A.4.

62A.3 Profile Definitions

The following sections define the mandatory profiles for 10PASS-TS operation, in terms of bandplan, PSD mask, notching parameters and payload rate.

62A.3.1 Bandplan and PSD Mask Profiles

The spectral characteristics of 10PASS-TS communication on the copper medium are defined by a choice of bandplans and PSD Masks.

Each of 5 standard frequency bands (Band 0, D1, U1, D2, U2) used for 10PASS-TS communication are defined in a bandplan. 10PASS-TS PHYs operating in the same cable bundle should use the same bandplan to ensure spectral compatibility. Furthermore, the selection of bandplan may be governed by regional regulations that pertain to the deployment. While all 10PASS-TS PHYs may operate in any of the below bandplans, installers should be aware of any regulations that might restrict their choice of modes. Bandplans may specify the use of 2, 3, 4 or 5 standard frequency bands.

PSD Masks further define the spectral environment by specifying the maximum transmit power spectral density at a given frequency. Like bandplans, the PSD mask should be selected to be compatible with applicable regulations and to match other PHYs operating in the same cable bundle.

Profiles are defined here for various regulatory environments as well as for private installation. Additionally, operation with a bandplan or PSD mask not defined in this clause is supported by configuration through Clause 45 registers. All 10PASS-TS PHYs shall be capable of operating in all profiles listed in this Clause. Profile definitions are listed in Table 62A-1.

Table 62A-1—Bandplan and PSD Mask Profiles

Profile Number	Bandplan	PSD Mask	Band Assignment[a]
1	G.993.1 Bandplan A	T1.424 -Trial Use Part 1 FTTCab	x/D/U/D/U
2	G.993.1 Bandplan A	T1.424 -Trial Use Part 1 FTTEx	x/D/U/D/U
3	G.993.1 Bandplan A	T1.424 -Trial Use Part 1 FTTCab	D/D/U/D/U
4	G.993.1 Bandplan A	T1.424 -Trial Use Part 1 FTTEx	D/D/U/D/U
5	G.993.1 Bandplan A	T1.424 -Trial Use Part 1 FTTCab	U/D/U/D/x
6	G.993.1 Bandplan A	T1.424 -Trial Use Part 1 FTTEx	U/D/U/D/x
7	G.993.1 Bandplan B	TS1 101 270-1 FTTEx	x/D/U/D/U
8	G.993.1 Bandplan B	TS1 101 270-1 FTTCab	x/D/U/D/U
9	G.993.1 Bandplan B	TS1 101 270-1 FTTEx	D/D/U/D/U
10	G.993.1 Bandplan B	TS1 101 270-1 FTTCab	D/D/U/D/U
11	G.993.1 Bandplan B	TS1 101 270-1 FTTEx	U/D/U/D/x
12	G.993.1 Bandplan B	TS1 101 270-1 FTTCab	U/D/U/D/x

[a]For each band in the bandplan, the Band Assignment indicates the use or direction of communication for that band. U=upstream, D=downstream, x=band is unused. Bands are listed in this order: 0/1/2/3/4

62A.3.2 Bandplan definitions

The management entity should load the appropriate Clause 45 registers according to the bandplan specified by the selected profile. Informative Annex 62C contains examples of the use of Clause 45 registers for the purpose of setting profiles.

62A.3.2.1 ITU-T approved bandplans

The VDSL bandplans defined in ITU-T Recommendation G.993.1 shall be supported by all 10PASS-TS PMDs. These bandplans are represented for information in Table 62A-2.

62A.3.2.2 Newly approved bandplan

TBD

62A.3.3 PSD mask definitions

Table 62A-2—Bandplans defined by ITU-T Recommendation G.993.1

Plan	Band 0 (optional) US/DS	Band D1	Band U1	Band D2	Band U2
Bandplan A (formerly Plan 998)	25 kHz - 138 kHz	138 kHz - 3.75 MHz	3.75 Mhz - 5.2 MHz	5.2 MHz - 8.5 MHz	8.5 MHz - 12 MHz
Bandplan B (formerly Plan 997)	25 kHz - 138 kHz	138 kHz - 3.0 MHz	3.0 MHz - 5.1 MHz	5.2 MHz - 7.05 MHz	7.05 MHz - 12 MHz
Bandplan C[a]	25 kHz - 138 kHz	138 kHz - 2.5MHz	2.5 MHz - 3.75 MHz	3.75 MHz - *Fx*	*Fx* - 12MHz
Annex F	TBD				

[a]Bandplan C is characterized by a variable split frequency between band D2 and band U2, represented as "*Fx*". 10PASS-TS shall support operation in Bandplan C for $Fx = 3750\text{kHz} + n \times 250\text{kHz}$, where $0 \le n \le 33$.

Editor's Note: To be completed.

62A.3.4 Band Notch Profiles

In certain deployments, 10PASS-TS operation may interfere with nearby amateur radio equipment. The Band Notch profiles specify notches that 10PASS-TS PHYs shall add to their transmit PSDs when selected. When a notch is activated, the transmitter shall reduce its PSD to less than -80 dBm/Hz in the frequencies of the notch. More than one notch may be activated at one time.

All Band Notches specified in the following standards shall be supported:

a) ITU-T Recommendation G.993.1 Annex F, Table F-5
b) T1.424/Trial-Use Part 1, Clause 15
c) ETSI TS1 101 270 subclause 9.3.3.6.1

The Band Notch Profiles are listed for information in Table 62A-3

62A.3.5 Payload Rate Profiles

The Payload Rate Profile describes the payload bitrate as seen at the MII interface.

The Payload Rate Profile consists of a payload rate for each of the downstream and upstream directions. The profile is specified in the format *Drate/Urate* as the minimum payload rate required, where *Drate* and *Urate* are expressed in Mb/s. For example a Payload Rate Profile of 10/3 corresponds to a downstream payload rate of 10 Mb/s and an upstream payload rate of 3 Mb/s. *Drate* values of 2.5, 5, 7.5, 10, 12.5, 15, 25, 35 and 50 shall be supported where the loop environment, bandplan and PSD mask allow this. *Urate* values of 2.5, 5, 7.5, 10, 12.5, 15, 25, 35 and 50 shall be supported where the loop environment, bandplan and PSD mask allow this. This leads to a total of 9 symmetric and 72 asymmetric Payload Rate Profiles.

The selected Payload Rate Profile sets a target for the PHY's operation. If the payload rates of the selected profile cannot be achieved based on the loop environment, bandplan and PSD mask, the PHY shall drop the link.

62A.3.6 Complete Profiles

Table 62A-3—Band Notch Profile Definitions

Band Notch Profile	Specification	Start Frequency (KHz)	End Frequency (KHz)
1	ITU-T/ETSI #1	1,810	2,000
2	ITU-T/ETSI #2	3,500	3,800
3	ITU-T/ETSI #3	7,000	7,100
4	ITU-T/ETSI #4	10,100	10,150
5	T1.424 #2	2,500	4,000
6	T1.424 #3	7,000	7,300
7	T1.424 #5	14,000	14,350
8	T1.424 #6	18,068	18,168
9	T1.424 #7	21,000	21,450
10	T1.424 #8	24,890	24,990
11	T1.424 #9	28,000	29,700

The complete PMD operation of the 10PASS-TS PHY can be selected by choosing one Bandplan and PSD Mask profile, one Payload Rate Profile and any number of Band Notch Profiles.

62A.4 Register settings

Editor’s Note: Provide register settings for all listed profiles here.

Annex 62B

(normative)

Performance guidelines for 10PASS-T PMD profiles

Editors' Notes: *To be removed prior to final publication.*

Normative References:

Informative References:

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):

Revision History:

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Annex 62C

(informative)

10PASS-TS Examples

Editors' Notes: *To be removed prior to final publication.*

Normative References:

Informative References:

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):

Revision History:

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Editor's Note: This Annex is new in D1.414. It was created by the Editor under the license granted in the resolution of comment #63006/D1.3, to describe "that Clause 45 control may be used to override the profiles listed in this clause within the capabilities of Clause 62".

62C.1 Introduction

Annex 62A contains profiles for deployment of 10PASS-TS in typical environments, as well as for testing purposes. Certain situations may require the full use of the 10PASS-TS PHY's flexibility, going beyond what is offered by the predefined profiles, in order to obtain optimal performance. Examples of such circumstances:

a) the 10PASS-TS system shares a cable bundle with a legacy system; the PSD mask must be configured to minimize crosstalk between 10PASS-TS and the legacy system
b) for a specific application, a particular symmetry ratio is required, which is not easily obtained with the standard band plans
c) the desired payload bit rates are beyond the ones that can be set by means of the standard payload rate profiles
d) ...

To use this flexibility, the 10PASS-TS equipment must be configured by means of the appropriate Clause 45 registers. This Annex provides examples of such configurations.

62C.2 Bandplan configuration

Example situation: a user wishes to implement a custom bandplan for a 10PASS-TS deployment in a private network, in order to minimize near-end crosstalk to and from a certain legacy system. **Editor's Note: Band plan examples to be added.**

62C.2.1 SCM Example

In SCM, band plans can be configured by moving around the center frequency of the two upstream carriers and the two downstream carriers, and adjusting symbol rate to obtain a certain bandwidth. The center frequency is governed by the Center Frequency register (45.4.1.11) and the NT Center Frequency register (45.4.1.10). The symbol rate can be adjusted with the Symbol Rate register (45.4.1.5) and the NT Symbol Rate register (45.4.1.6).

62C.2.2 MCM Example

In MCM, band plans can be configured by selecting any group of tones in the Tone Group register (45.5.1.2), and allocating them to either upstream or downstream by setting the tone direction bit to the appropriate value (0=downstream, 1=upstream) in the Tone Control Parameter register (45.5.1.3). This procedure is repeated until the desired number of frequency bands has been allocated. The new configuration is applied by writing binary 1 to the Change Tone Direction bit in the Tone Control Action register (45.5.1.4).

62C.3 PSD mask configuration

Example situation: a mixed (transitional) deployment where certain subscribers are served with a 10PASS-TS line from a central office (longer lines), while others are served with a 10PASS-TS line from a cabinet (shorter lines). In order to guarantee high link quality for all subscribers, the transmit PSDs from the cabinet are masked to mimic a longer line (downstream power back-off). **Editor's Note: PSD examples to be added.**

62C.3.1 SCM Example

In SCM, the transmit power of the two upstream carriers and the two downstream carriers can be set by means of the TX PSD Level register (45.4.1.11) and the NT TX PSD Level register (45.4.1.12). After completion of the PSD configuration, the new configuration is activated by writing binary 1 to the Activate NT TX PSD level (45.4.1.1.8). **Editor's Note: concrete example has to be added here.**

62C.3.2 MCM Example

In MCM, the properties of the different tones are configured by means of the Tone Group register (1.x.15:0; 1.x+1.15:0, defined in 45.5.1.2). The 8-bit PSD Level field in the Tone Control Parameter register (45.5.1.3) is used to set the TX PSD level for the selected group of tones. Given the tone spacing of 4.3125 kHz or 8625 kHz, a very fine-grained PSD control is possible. To implement a gradual frequency-dependent power back-off, a narrow sliding window is defined in the Tone Group register; each time the window is moved towards higher frequencies, the allowed TX PSD for that frequency range is set. The new configuration is applied by writing binary 1 to the Change PSD Level bit in the Tone Control Action register (45.5.1.4). This approach is illustrated by the algorithm in Figure 62C–1.

```
for (tone=0;tone<4096;tone+=16) {
        set Tone Group register to [tone,tone+16];
        set PSD Level register to MaxPSD(tone);
}
Change PSD Level = 1;
```

Figure 62C–1—Use of Tone Group register to set user-defined frequency-dependent PSD Mask in MCM.

62C.4 RFI notch configuration

Editor's Note: Examples to be completed.

62C.4.1 SCM Example

62C.4.2 MCM Example

62C.5 Payload rate configuration

Editor's Note: Examples to be completed

62C.5.1 SCM Example

62C.5.2 MCM Example

Annex 63A

(normative)

PMD Profiles for 2BASE-TL

Editors' Notes:

References:
ITU-T Recommendation G.991.2.

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):

Revision History:
Draft 1.3 February 2003 Prelimnary draft for IEEE P802.3ah Task Froce review
Draft 1.414 April 2003: Incorporating comments against D1.3.

63A.1 Introduction and rationale

Annex 63A defines the PMD profiles for 2BASE-TL. These profiles define the transmission characteristics of the PHY on the media. 2BASE-TL PHYs are required to operate across varying media quality, regulatory and noise environments. The profiles defined in this clause have two purposes.

The first is to describe a bounded set of operating modes that a party might choose from when implementing, integrating and installing 2BASE-TL equipment. 2BASE-TL PHYs are inherently flexible in their transmission capabilities. The defined profiles collect a subset of these parameters into modes that work well in most deployments. For deployments that require an operating mode not defined in this Annex, profiles can be overridden by setting PHY PMD registers directly, via Clause 45 for example.

The second purpose of the profiles is to define a set of operating modes against which PHY performance compliance may be tested. The topic of performance compliance is addressed for 2BASE-TL in Annex 63B.

63A.2 Relationship to other clauses

Clause 30 [see Clause 30] describes how the selection of Annex 63A profiles is exported to a management entity.

Clause 45 registers describe an optional mechanism for configuring a 2BASE-TL PHY to use a particular profile. The register settings for each profile are contained in 63A.x.y.z

Editor's Note: Register settings to be added.

63A.3 Profile Definitions

A 2BASE-TL profile is characterized by 4 parameters: data rate, power, constellation size and region. Different regions have different constraints on the PHY. ITU-T Recommendation G.991.2 distinguishes 3 regions and lists regional requirements in three annexes labeled A, B, C. Reference Annex A generally describes those specifications that are unique to SHDSL systems operating under conditions such as those typically encountered within the North American network; Reference Annex B, within European networks; and Reference Annex C, within networks with existing TCM-ISDN service.

The profiles of Table 63A-1will generate a net data rate greater than 2 Mb/s at the MII interface on M pairs where M is between 1 and 4. Note that the profiles are defined on a single pair basis. The aggregation mechanism is outside the scope of this Annex. The data rate is the closest multiple of 64 kb/s greater than a net data rate of 2 Mb/s plus the corresponding 64/65B encapsulation overhead divided by M. The line rate has an additional 8 kb/s of SHDSL overhead.

Table 63A-1—2BASE-TL profiles

Profile #	Data rate per pair (kb/s)	Line rate per pair (kb/s)	Power (dBm)	Region	Constellation
1	2048	2056	13.5	Annex A sec. A.4.1	16-TCPAM
2	1024	1032	13.5	Annex A sec. A.4.1	16-TCPAM
3	704	712	13.5	Annex A sec. A.4.1	16-TCPAM
4	512	520	13.5	Annex A sec. A.4.1	16-TCPAM
5	2048	2056	14.5	Annex B sec. B.4.1	16-TCPAM
6	1024	1032	13.5	Annex B sec. B.4.1	16-TCPAM
7	704	712	13.5	Annex B sec. B.4.1	16-TCPAM
8	512	520	13.5	Annex B sec. B.4.1	16-TCPAM
9	3072	3080	13.5	Annex A sec. A.4.1 & Annex B sec. B.4.1	32-TCPAM

Annex 63B

(normative)

Performance guidelines for 2BASE-TL PMD profiles

Editors' Notes: *To be removed prior to final publication.*

Normative References:

Informative References:

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):

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Draft 1.414 April 2003	Incorporating comments against D1.3.

63B.1 Introduction and rationale

Annex 63B defines performance guidelines for 2BASE-TL PMD profiles. The definition of those guidelines is challenging due to the varying nature of the access network. The access network has large variations in cable characteristics from region to region. In addition, the make-up of a cable can encompass multiple cable gauges and/or different configuration of bridged taps. Finally, services may vary from region to region creating different noise scenarios. Typically, deployment guidelines are a function of the telecommunications operator, which is operating a loop and the regional spectrum management policies, which govern deployment on that loop.

Given that one cannot test every possible combination of loop make-up and noise conditions, the performance guidelines are covered from two perspectives. Firstly, 63B.3 lists a suite of artificial tests crafted to test the 2BASE-TL PHYs under representative worst-case noise and loop conditions. Secondly, 63B.4 defines a deployment guideline rule which allows a service provider to determine whether a given loop will support a given profile.

63B.2 Relationship to other clauses

Annex 63A lists a set of PMD profiles for 2BASE-TL.

Clause 30 [see Clause 30] describes how the selection of Annex 63A profiles is exported to a management entity.

Clause 45 registers describe an optional mechanism for configuring a 2BASE-TL PHY to use a particular profile. The register settings for each profile are contained in 63A.x.y.z

63B.3 Performance Test Cases.

Profile 1 shall successfully pass the corresponding test described in Table A-1 of G.991.2.

Editor's note: There are no test in G.991.2 specifically defined to test the 1024, 704 and 512kbps rates. One could define completely new tests, however this would necessitate new test equipment. The tests in Table 63B-1 reuse the noise shapes defined for the existing 768kbps. The length of the loop is adjusted in order to challenge the Device Under Test (DUT) in the same way as for the other rates.

The profiles associated with the 1024, 704 and 512 kb/s (profiles 2, 3 and 4) shall satisfy the tests described in Table 63B-1. The same test methodology defined in G.991.2 Annex A shall be applied. The test cases are numbered 57 to 74 to differentiate them from the existing tests 1 to 56 in Table A-1 of G.991.2.

Profile 5, 6 and 8 shall be tested using the tests defined in Annex B of ITU-T Recommendation G.991.2. The loops defined in Annex B do not scale as well as the loops of Annex A because they are defined in terms of insertion loss at a given frequency (with a granularity of 0.5 dB), rather than a length in meters. The 704 kb/s data rate (profile 7) is expected to successfully pass the test associated with the 768 kb/s data rate. Therefore, for Annex B testing, the 704 kb/s data rate will be tested using the 768 kb/s test.

63B.4 Deployment Guidelines

The ITU-T G.991.2 defines an equivalent loop attenuation which can be used to determine whether a cable insertion loss function 1/H(f),can support a given profile associated with a nominal transmit signal power

Table 63B-1—Additional tests for the Annex A 1024 & 704 kb/s data rate

Test	Test loop	L (km)	Test unit	Payload data rate (kb/s)	PSD	Interferer Combination	Required Margin (dB)
57	S	2.80	2BASE-TL-O	1024	symmetric	49-HDSL	5 + Δ*
58	BT1-C	2.47	2BASE-TL-O	1024	symmetric	49-SHDSL_768_sym	5 + Δ*
59	BT1-C	2.47	2BASE-TL-O	1024	symmetric	49-HDSL	5 + Δ*
60	S	2.83	2BASE-TL-R	1024	symmetric	49-HDSL	5 + Δ*
61	BT1-R	2.47	2BASE-TL-R	1024	symmetric	49-SHDSL_768_sym	5 + Δ*
62	BT1-R	2.47	2BASE-TL-R	1024	symmetric	49-HDSL	5 + Δ*
63	S	3.44	2BASE-TL-O	704	symmetric	49-HDSL	5 + Δ*
64	BT1-C	3.17	2BASE-TL-O	704	symmetric	49-SHDSL_768_sym	5 + Δ*
65	BT1-C	3.17	2BASE-TL-O	704	symmetric	49-HDSL	5 + Δ*
66	S	3.44	2BASE-TL-R	704	symmetric	49-HDSL	5 + Δ*
67	BT1-R	3.17	2BASE-TL-R	704	symmetric	49-SHDSL_768_sym	5 + Δ*
68	BT1-R	3.17	2BASE-TL-R	704	symmetric	49-HDSL	5 + Δ*
69	S	4.08	2BASE-TL-O	512	symmetric	49-HDSL	5 + Δ*
70	BT1-C	3.75	2BASE-TL-O	512	symmetric	49-SHDSL_768_sym	5 + Δ*
71	BT1-C	3.75	2BASE-TL-O	512	symmetric	49-HDSL	5 + Δ*
72	S	4.08	2BASE-TL-R	512	symmetric	49-HDSL	5 + Δ*
73	BT1-R	3.75	2BASE-TL-R	512	symmetric	49-SHDSL_768_sym	5 + Δ*
74	BT1-R	3.75	2BASE-TL-R	512	symmetric	49-HDSL	5 + Δ*

spectral density S(f). The loop attenuation should not be confused with another popular metric called the loop insertion loss at a given frequency. The latter specifies the insertion loss of the loop at a single frequency while the former weights the transmitted signal PSD and insertion loss of the loop over a frequency range corresponding to the transmitted signal bandwidth. The loop attenuation provides a more precise estimate of the loop capability to support a given data rate.

The SHDSL Loop Attenuation shall be defined as follows (section 9.5.5.7.5 of G.991.2):

$$LoopAtten_{SHDSL}(H) = \frac{2}{f_{\mathrm{Baud}}}\left(\begin{array}{l} \displaystyle\int_0^{\frac{f_{\mathrm{Baud}}}{2}} 10\log\left[\sum_{n=0}^{1} S(f-nf_{\mathrm{Baud}})\right]df - \\ \displaystyle\int_0^{\frac{f_{\mathrm{Baud}}}{2}} 10\log\left[\sum_{n=0}^{1} S(f-nf_{\mathrm{Baud}})\left|H(f-nf_{\mathrm{Baud}})\right|^2\right]df \end{array}\right) \tag{1}$$

where f_{Baud} is the symbol rate, $1/H(f)$ is the insertion loss of the loop, and $S(f)$ is the nominal transmit PSD.

Table 63B-2 lists the maximum loop attenuation for a margin of 5 dB assuming the presence of 49 and 12 self-interferers for the profiles defined in Annex 63A. The 49 self-interferer case corresponds to a very conservative deployment reach.

Assuming a data rate of 2048 kb/s, the deployment reach for AWG24 gauge cable corresponds to 2.8 km for the 49-self number and 3.2 km for the 12-self number.

Table 63B-2—Loop attenuation guideline

Profile	Data rate (kb/s)	Maximum SHDSL Loop Attenuation for 49-self-interferers	Maximum SHDSL Loop Attenuation for 12-self-interferers
1 & 5	2048	24.0	27.7
3 & 6	1024	28.6	32.1
4 & 7	704	31.0	34.7
5 & 8	512	33.1	36.7

Annex 66A

(informative)

Environmental Characteristics for Ethernet Subscriber Access Networks

Editors' Notes: *To be removed prior to final publication.*

Normative References:

Informative References:

Definitions (to be added to 1.4):

Abbreviations (to be added to 1.5):

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Draft 1.414 April 2003	Draft 1.414 for IEEE P802.3ah Task Force review

66A.1 Introduction

The purpose of IEEE 802.3ah (EFM), and its distinction from traditional Ethernet networks, is that it specifies functionality required for the subscriber access network, i.e., public network access. Network design considerations for "public" access that may differ from traditional Ethernet LANs include the operation, administration and management (OAM) function, and the regulatory requirements, as well as the environmental factors which are addressed in this annex.

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Implementers are expected to indicate in their literature the operating environmental conditions to facilitate selection, installation, and maintenance, and may also give summary information on a product label. The normative specifications of this standard are understood to apply over the range of conditions defined by the implementer.

This informative annex provides information, to both the design engineer and the eventual user of specific product implementations, on the environmental factors to be considered when designing EFM network topologies. It is intended to record the assumptions used in developing the specifications contained in the normative specifications. The following sections give an example of likely deployment of the different physical layer types, followed by a discussion of temperature issues. Informative references may be found in Annex ref.

It is believed that the most critical environmental factor on an Ethernet terminal will be temperature and that the most temperature sensitive element in a link is the semiconductor laser. The temperature sensitivity of these components may impact potential deployment scenarios if not considered. The remaining environmental factors (humidity, vibration, etc.) are not considered to be of major importance and may be handled by conventional design practice. Therefore, the remainder of this annex addresses temperature.

66A.1.1 Terminal deployment scenarios

The terminal equipment of a link may or may not be in a weatherprotected environment. 100BASE-LX10 links may be widely deployed with conventional building cabling for general purpose IT applications, as well as in Ethernet subscriber access applications. The other link types in Table 66–1 are intended for Ethernet subscriber access applications. The table gives an example deployment scenario. Other scenarios are also supported by this standard, and may be deployed in significant numbers.

Table 66–1—Informative deployment examples

Head end (nearer the core of the network	Customer premises (nearer the periphery of the network)
Weatherprotected	**Not weatherprotected or weatherprotected**
100BASE-LX10	100BASE-LX10
100BASE-BX10-D	100BASE-BX10-U
1000BASE-LX10	1000BASE-LX10
1000BASE-BX10-D	1000BASE-BX10-U
1000BASE-PX10-D	1000BASE-PX10-U
1000BASE-PX20-D	1000BASE-PX20-U
10PASS-T	10PASS-T
2BASE-TL	2BASE-TL

This example scenario places the customer premises equipment in a non-weatherprotected position, e.g. the outside wall of a house, to allow ease of access for installation and maintenance. Where the premises is a large building such as a hotel, apartment block or office, a space such as a basement within the building may be accessible enough.

It is expected that the physical format of the equipment at each end of the link will be different; however, this is outside the scope of the standard. The physical layer type (e.g. 2BASE-TL) and the PMD type (e.g. 1000BASE-PX20-U) are classifications of the signal on the line, and do not imply a temperature range or physical format.

66A.2 Temperature

Large portions of Ethernet Subscriber Access optical and copper links are expected to operate in environmental conditions consistent with the outside plant. However, it is recognized that the exact requirements for a particular deployment will vary greatly depending on the geographic location, system structure, and governing regulations. It is also recognized that portions of the network may be deployed in more benign and protected environments and that in some geographic location the outside environment may also be considered benign.

There are many factors. The temperatures in coastal regions are not usually extreme. Tropical regions are usually hot or hot and wet. The widest temperature swings are found in dry regions in the interior of large continents, e.g. central North America or central Asia. High altitude may reduce the efficacy of air cooling systems. To an extent, this is offset by the typically cooler air temperature at high altitude. Direct sunshine can add up to 1120 W/m^2 heating.

As a reference, Table 66–2 shows the annual extreme air temperature values for the nine classes of climates from IEC 60721-2-1.

Table 66–2—Informative listing of climate types

Type of Climate	Low Temperature (°C)	High Temperature (°C)
Extremely cold (except the Central Antarctic)	-65	+32
Cold	-50	+32
Cold temperate	-33	+34
Warm temperate	-20	+35
Warm dry	-20	+40
Mild warm dry	-5	+40
Extremely warm dry	+3	+55
Warm damp	+5	+40
Warm damp, equable	+13	+35

The climate is the basic determining factor in the component temperature. However, the temperature of the equipment using the component is significantly modified by a number of factors related to the location of the equipment. Some of these are:

— Is the equipment location weatherprotected or non-weatherprotected
— Is the building temperature controlled
— Are locations without temperature control subject to solar heating

Equipment temperatures for a number of locations from ETSI and Telcordia documents are shown in Table 66–3.

An additional factor is the internal thermal design of the equipment using the optical component. The component temperature will be higher than the equipment ambient and the increase will be implementation dependant. For equipment with the complexity of EFM systems an internal temperature rise of 15ºC to 20ºC may be anticipated.

Table 66–3—Informative listing of equipment temperature ranges

Climate or location	Specified ambient temperature	Reference
Weatherprotected		
Telecom control rooms	15 to 30°C	ETSI Class 3.6
Temperature controlled	5 to 40°C (-5 to 45°C with cooling failure)	ETSI Class 3.1
Controlled - long term	5 to 40°C (-5 to 50°C short term)	Telcordia GR-63
Partly temperature-controlled	-5 to 45°C	ETSI Class 3.2
Not temperature-controlled	-25 to 55°C	ETSI Class 3.3
Sheltered locations	-40 to 40°C	ETSI Class 3.5
Extended/uncontrolled	-40 to 46°C (-40 to 65°C inside enclosure)	Telcordia GR-487, GR-468
Sites with heat trap	-40 to 70°C	ETSI Class 3.4
Non-weatherprotected		
Temperate	-33 to 40°C	ETSI Class 4.1
Extended	-45 to 45°C	ETSI Class 4.1E
Extremely cold	-65 to 35°C	ETSI Class 4.2L
Extremely warm dry	-20 to 55°C	ETSI Class 4.2H

66A.3 Temperature impact on optical components

Components are often commercially available in two grades, 0 to 70°C and -40 to 85°C, although optoelectronic components are also available in -20 or -10 to 85°C grade, depending on format. The GBIC MSA requires an operating temperature range of 0 to 50°C in moving air. Because of the varied physical format of equipment and components, the reader is advised to refer to specific product literature or multi source agreements for precise information.

The most temperature sensitive sub-component in an Ethernet terminal is expected to be the semiconductor laser, if for a fiber optic link. There are two categories of laser presently commonplace in the physical layers addressed here; Fabry-Perot (FP), a type of multi longitudinal mode (MLM) laser, and distributed feedback (DFB), a type of single longitudinal mode (SLM) laser.

Fabry-Perot lasers may have a temperature coefficient of wavelength around 0.45 nm/K, so the operating wavelength of a particular FP may vary by 55 nm over the range -40 to 85 °C. The operating wavelength windows within this standard are generally 100 nm wide where FPs are anticipated, allowing adequate margin for manufacturing tolerances. To allow for the widest variety of implementation the spectral width is specified as a function of wavelength where appropriate. However, the requirement for low error rates over substantial distances of fiber, as specified by transmitter and dispersion penalty (TDP), forces the implementer of 1000 Mb/s FP laser based implementations to pay careful attention to both wavelength and spectral width to avoid excessive mode partition noise. In practice, the full range of wavelengths in the standard is not actually available for use because at the temperature extremes the required spectral width would be too narrow. It can be seen that the wider the temperature range required, the more precisely the wavelength and spectral width must be contained to achieve a particular reach. This may have an impact on cost. This consideration would be expected to apply to 1000BASE-LX10, 1000BASE-BX10-U and 1000BASE-PX10-U.

Where the dispersion of the link or the wavelength limits are more demanding than can be met cost-effectively with FPs, DFBs may be used. They may have a temperature coefficient of wavelength under 0.1 nm/K and much narrower spectral widths than FPs. Because only a single longitudinal mode is present, a DFB does not suffer from mode partition noise. DFBs are generally more expensive than FPs. A DFB's lasing wavelength varies at 0.1 nm/°C while its gain peak varies at around 0.45 nm/K. At extremes of temperature these two wavelengths are far apart and the laser may perform poorly. For this reason, DFBs for extended temperature range may be more expensive again. This consideration would be expected to apply to 1000BASE-BX10-D, 1000BASE-PX10-D and 1000BASE-PX20.

66A.3.1 Component case temperature recommendations

Clause 66A.3 discussed the temperature progression from climate to equipment to component. Clause 66A.4 discussed the impact of temperature, and particularly temperature range, on the design and cost of laser based optical components. In order to balance these two effects, contain costs, and yet cover the widest range of climates to allow access to the greatest markets the following recommendations are made.

Two component case temperature ranges, and by inference a third, are developed. These are defined as follows:

— Warm Extended: Intended for outdoor application in warmer climate locations.
— Cool Extended: Intended for outdoor applications in cooler climate locations.
— Universal Extended: (This is not a separate class, but is defined by simultaneously complying with the Warn and Cool Extended temperature ranges) This is a combination of the requirements for the Warm Extended and Cool Extended Classes and is intended for general outdoor applications in areas with wide seasonal variations or those designs intended for deployment in multiple geographic locations.

The recommended component case temperature ranges for these two classes are shown in Table 66A-4.

Table 66–4—Component case temperature class recommendations

Class	Low Temperature (°C)	High Temperature (°C)
Warm Extended	-5	+85
Cool Extended	-30	+60
Universal Extended	-30	+85

It will be noted that the recommendations of Table 66–4 do not address the extremely cold climates of Table 66–2 or the cold non-weatherprotected equipment requirements of Table 66–3. In these geographic locations it is common practice to avoid non-weatherprotected locations for systems of EFM complexity and place the equipment indoors. In addition, a number of North American telcos deploy outdoor equipment in locations with a -40ºC minimum temperature. This market may be addressed by employing the Universal Extended temperature range with an additional 10ºC on the cold end.

These temperature ranges are optional and conformance with these ranges is not required. This allows lower cost components to be had for those applications that require less extreme temperature ranges. This may be done by taking advantage of the reduced wavelength change to ease the central wavelength tolerance and spectral width requirements from the trade-off curves and more particularly, the TDP limit. This allows equipment and component suppliers, at their discretion, to develop systems and components that tolerate less severe environmental conditions that they view as suitable for their market as long as the PMD is consistent with the PICS proforma of the relevant clause. This limitation assures interoperability while allowing the equipment to be developed for specific markets.

References

[B1] IEC 60721-2-1, "Classification of environmental conditions - Part 2-1: Environmental conditions appearing in nature - Temperature and humidity", Edition 1.1

[B2] 2. IEC 62149-1, "Fiber optics active components and devices: Performance standards - Part 1: General and guidance", Draft standard