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IEEE Standard for Ethernet

IEEE Computer Society

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USA

IEEE Std 802.3™-2015
(Revision of
IEEE Std 802.3-2012)

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Abstract: Ethernet local area network operation is specified for selected speeds of operation from 1 Mb/s to 100 Gb/s using a common media access control (MAC) specification and management information base (MIB). The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol specifies shared medium (half duplex) operation, as well as full duplex operation. Speed specific Media Independent Interfaces (MIIs) allow use of selected Physical Layer devices (PHY) for operation over coaxial, twisted pair or fiber optic cables, or electrical backplanes. System considerations for multisegment shared access networks describe the use of Repeaters which are defined for operational speeds up to 1000 Mb/s. Local Area Network (LAN) operation is supported at all speeds. Other specified capabilities include: various PHY types for access networks, PHYs suitable for metropolitan area network applications, and the provision of power over selected twisted pair PHY types.

Keywords: 10BASE; 100BASE; 1000BASE; 10GBASE; 40GBASE; 100GBASE; Fast Ethernet; 10 Gigabit Ethernet; 40 Gigabit Ethernet; 100 Gigabit Ethernet; attachment unit interface; AUI; Auto Negotiation; Backplane Ethernet; data processing; DTE Power via the MDI; EPON; Ethernet; Ethernet in the First Mile; Ethernet passive optical network; Fast Ethernet; Gigabit Ethernet; GMII; IEEE 802.3™; information exchange; local area network; management; medium dependent interface; media independent interface; MDI; MIB; MII; XGMII; PHY; physical coding sublayer; Physical Layer; physical medium attachment; PMA; Power over Ethernet; repeater; type field; VLAN TAG

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Introduction

This introduction is not part of IEEE Std 802.3™-2015, IEEE Standard for Ethernet.

IEEE Std 802.3™ was first published in 1985. Since the initial publication, many projects have added functionality or provided maintenance updates to the specifications and text included in the standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba™-2010).

The half duplex Media Access Control (MAC) protocol specified in IEEE Std 802.3-1985 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was key to the experimental Ethernet developed at Xerox Palo Alto Research Center, which had a 2.94 Mb/s data rate. Ethernet at 10 Mb/s was jointly released as a public specification by Digital Equipment Corporation (DEC), Intel and Xerox in 1980. Ethernet at 10 Mb/s was approved as an IEEE standard by the IEEE Standards Board in 1983 and subsequently published in 1985 as IEEE Std 802.3-1985. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3. A full duplex MAC protocol was added in 1997.

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3z added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile) and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2015 and are not maintained as separate documents.

At the date of IEEE Std 802.3-2015 publication, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2015

Section One—Includes Clause 1 through Clause 20 and Annex A through Annex H and Annex 4A. Section One includes the specifications for 10 Mb/s operation and the MAC, frame formats and service interfaces used for all speeds of operation.

Section Two—Includes Clause 21 through Clause 33 and Annex 22A through Annex 33E. Section Two includes management attributes for multiple protocols and speed of operation as well as specifications for providing power over twisted pair cabling for multiple operational speeds. It also includes general information on 100 Mb/s operation as well as most of the 100 Mb/s Physical Layer specifications.

Section Three—Includes Clause 34 through Clause 43 and Annex 36A through Annex 43C. Section Three includes general information on 1000 Mb/s operation as well as most of the 1000 Mb/s Physical Layer specifications.

Section Four—Includes Clause 44 through Clause 55 and Annex 44A through Annex 55B. Section Four includes general information on 10 Gb/s operation as well as most of the 10 Gb/s Physical Layer specifications.

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines services and protocol elements that enable the exchange of IEEE Std 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification.

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Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

Section Six—Includes Clause 78 through Clause 95 and Annex 83A through Annex 93C. Clause 78 specifies Energy-Efficient Ethernet. Clause 79 specifies IEEE 802.3 Organizationally Specific Link Layer Discovery Protocol (LLDP) type, length, and value (TLV) information elements. Clause 80 through Clause 95 and associated annexes includes general information on 40 Gb/s and 100 Gb/s operation as well the 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

A companion document IEEE Std 802.3.1 describes Ethernet management information base (MIB) modules for use with the Simple Network Management Protocol (SNMP). IEEE Std 802.3.1 is updated to add management capability for enhancements to IEEE Std 802.3 after approval of the enhancements.

IEEE Std 802.3 will continue to evolve. New Ethernet capabilities are anticipated to be added within the next few years as amendments to this standard.

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SECTION TWO

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

24.1 Overview

24.1.1 Scope

This clause specifies the Physical Coding Sublayer (PCS) and the Physical Medium Attachment (PMA) sublayer that are common to a family of 100 Mb/s Physical Layer implementations, collectively known as 100BASE-X. There are currently two embodiments within this family: 100BASE-TX and 100BASE-FX. 100BASE-TX specifies operation over two pairs of twisted-pair Category 5 cabling. 100BASE-FX specifies operation over two optical fibers. The term 100BASE-X is used when referring to issues common to both 100BASE-TX and 100BASE-FX.

The 100BASE-X may support the capability of Energy-Efficient Ethernet (EEE) as described in Clause 78. When a transmitting station of a link with this capability detects low link utilization, it can request the local PHY transmitter to enter the Low Power Idle (LPI) mode and send appropriate symbols over the link. Upon receiving and decoding those symbols, the link partner's receiver can enter the LPI mode. The transmit and receive paths can enter and exit low power states independently. Energy is conserved by deactivating the corresponding functional blocks of individual path. Only 100BASE-TX supports this optional capability.

100BASE-X leverages the Physical Layer standards of ISO/IEC 9314 and ANSI X3T12 (FDDI) through the use of their Physical Medium Dependent (PMD) sublayers, including their Medium Dependent Interfaces (MDI). For example, ANSI X3.263-1995 (TP-PMD) defines a 125 Mb/s, full duplex signaling system for twisted-pair wiring that forms the basis for 100BASE-TX as defined in Clause 25. Similarly, ISO/IEC 9314-3:1990 defines a system for transmission on optical fiber that forms the basis for 100BASE-FX as defined in Clause 26.

100BASE-X maps the interface characteristics of the FDDI PMD sublayer (including MDI) to the services expected by the CSMA/CD MAC. 100BASE-X can be extended to support any other full duplex medium requiring only that the medium be PMD compliant.

24.1.2 Objectives

The following are the objectives of 100BASE-X:

a) Support the CSMA/CD MAC in the half duplex and the full duplex modes of operation.
b) Support the 100BASE-T MII, repeater, and optional Auto-Negotiation.
c) Provide 100 Mb/s data rate at the MII.
d) Support cable plants using Category 5 twisted-pair, 150 Ω STP or cabled optical fiber, compliant with ISO/IEC 11801.
e) Allow for a nominal network extent of 200–400 m, including
    1) Unshielded twisted-pair links of 100 m
    2) Two repeater networks of approximately 200 m span
    3) One repeater network of approximately 300 m span (using fiber)
    4) DTE/DTE links of approximately 400 m (half duplex mode using fiber) and 2 km (full duplex mode using multimode fiber.
f) Preserve full duplex behavior of underlying PMD channels.
g) Optionally support EEE through the function of LPI (see Clause 78), available only for 100BASE-TX.

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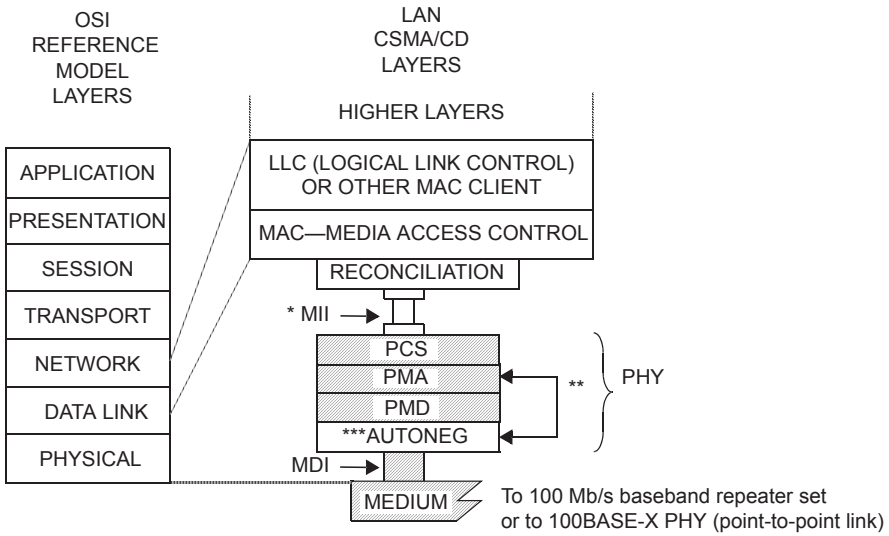
24.1.3 Relationship of 100BASE-X to other standards

Figure 24–1 depicts the relationships among the 100BASE-X sublayers (shown shaded), other 100BASE-T sublayers, the CSMA/CD MAC, and the IEEE 802.2 LLC.



MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
PMD = PHYSICAL MEDIUM DEPENDENT

* MII is optional.
** AUTONEG communicates with the PMA sublayer through the PMA service interface messages PMA_LINK.request and PMA_LINK.indicate.
*** AUTONEG is mandatory for EEE capability and optional otherwise.

Figure 24–1—Type 100BASE-X PHY relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

24.1.4 Summary of 100BASE-X sublayers

The following provides an overview of the 100BASE-X sublayers that are embodied in the 100BASE-X Physical sublayer (PHY).[5]

24.1.4.1 Physical Coding Sublayer (PCS)

The PCS interface is the Media Independent Interface (MII) that provides a uniform interface to the Reconciliation sublayer for all 100BASE-T PHY implementations (e.g., 100BASE-X and 100BASE-T4). 100BASE-X, as other 100BASE-T PHYs, is modeled as providing services to the MII. This is similar to the use of an AUI interface.

The 100BASE-X PCS realizes all services required by the MII, including the following:

a) Encoding (decoding) of MII data nibbles to (from) five-bit code-groups (4B/5B).
b) Generating Carrier Sense and Collision Detect indications.

[5] The 100BASE-X PHY should not be confused with the FDDI PHY, which is a sublayer functionally aligned to the 100BASE-T PCS.

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c) Serialization (deserialization) of code-groups for transmission (reception) on the underlying serial PMA.
d) Mapping of Transmit, Receive, Carrier Sense and Collision Detection between the MII and the underlying PMA.
e) Optionally, interpreting and generating MII data signals to enable or disable the LPI mode.

24.1.4.2 Physical Medium Attachment (PMA) sublayer

The PMA provides a medium-independent means for the PCS and other bit-oriented clients (e.g., repeaters) to support the use of a range of physical media. The 100BASE-X PMA performs the following functions:

a) Mapping of transmit and receive code-bits between the PMA's client and the underlying PMD.
b) Generating a control signal indicating the availability of the PMD to a PCS or other client, also synchronizing with Auto-Negotiation when implemented.
c) Optionally, generating indications of activity (carrier) and carrier errors from the underlying PMD.
d) Optionally, sensing receive channel failures and transmitting the Far-End Fault Indication; and detecting the Far-End Fault Indication.
e) Optionally, receiving and processing LPI control signals from the PCS.
f) Recovery of clock from the NRZI data supplied by the PMD.

24.1.4.3 Physical Medium Dependent (PMD) sublayer

100BASE-X uses the FDDI signaling standards ISO/IEC 9314-3:1990 and ANSI X3.263-1995 (TP-PMD). These signaling standards, called PMD sublayers, define 125 Mb/s, full duplex signaling systems that accommodate multimode optical fiber and twisted-pair cabling. 100BASE-X uses the PMDs specified in these standards with the PMD Service Interface specified in 24.4.1.

The MDI, logically subsumed within the PMD, provides the actual medium attachment, including connectors, for the various supported media.

100BASE-X does not specify the PMD and MDI other than including the appropriate standard by reference along with the minor adaptations necessary for 100BASE-X. Figure 24–2 depicts the relationship between 100BASE-X and the PMDs of ISO/IEC 9314-3:1990 (for 100BASE-FX) and ANSI X3.263-1995 (for 100BASE-TX). The PMDs (and MDIs) for 100BASE-TX and 100BASE-FX are specified in subsequent clauses of this standard.

24.1.4.4 Auto-Negotiation

Auto-Negotiation shall be implemented for EEE capability. See Clause 28.

24.1.5 Inter-sublayer interfaces

There are a number of interfaces employed by 100BASE-X. Some (such as the PMA and PMD interfaces) use an abstract service model to define the operation of the interface. The PCS Interface is defined as a set of physical signals, in a medium-independent manner (MII). Figure 24–3 depicts the relationship and mapping of the services provided by all of the interfaces relevant to 100BASE-X.

It is important to note that, while this specification defines interfaces in terms of bits, nibbles, and code-groups, implementations may choose other data path widths for implementation convenience. The only exceptions are: a) the MII, which, when implemented, uses a nibble-wide data path as specified in Clause 22, and b) the MDI, which uses a serial, physical interface.

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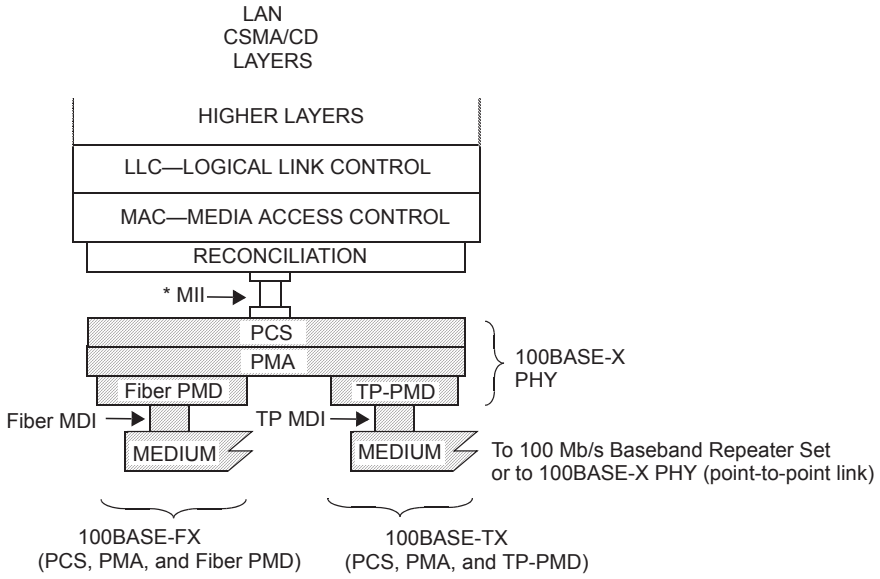

MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
Fiber PMD = PHYSICAL MEDIUM DEPENDENT SUBLAYER FOR FIBER
TP-PMD = PHYSICAL MEDIUM DEPENDENT SUBLAYER FOR TWISTED PAIRS

NOTE—The PMD sublayers are mutually independent.
* MII is optional.

Figure 24–2—Relationship of 100BASE-X and the PMDs

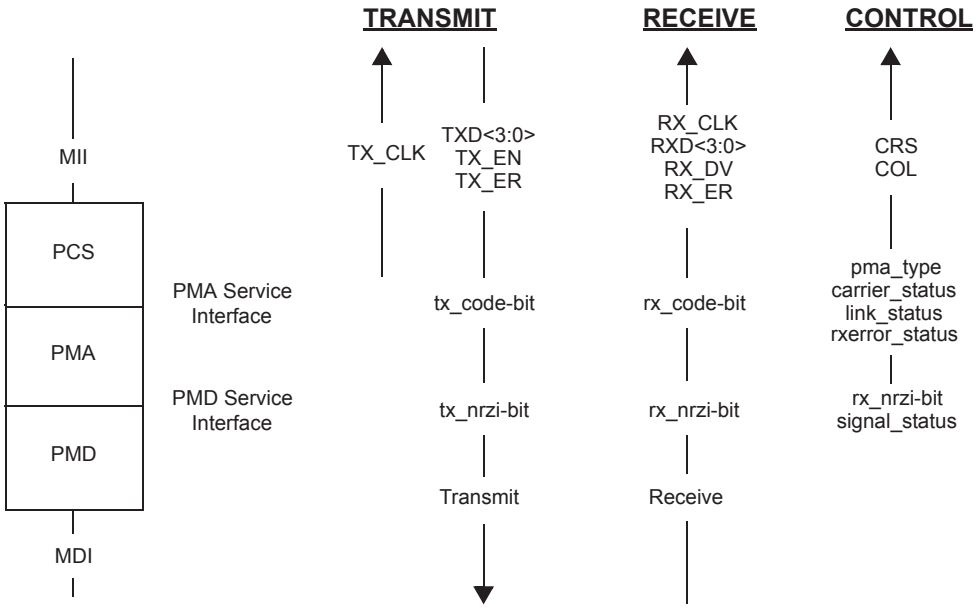

Figure 24–3—Interface mapping

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24.1.6 Functional block diagram

Figure 24–4 provides a functional block diagram of the 100BASE-X PHY. Signals or functions shown with dashed lines are optional.

24.1.7 State diagram conventions

The body of this standard is comprised of 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.

24.2 Physical Coding Sublayer (PCS)

24.2.1 Service Interface (MII)

The PCS Service Interface allows the 100BASE-X PCS to transfer information to and from the MAC (via the Reconciliation sublayer) or other PCS client, such as a repeater. The PCS Service Interface is precisely defined as the Media Independent Interface (MII) in Clause 22.

In this clause, the setting of MII variables to TRUE or FALSE is equivalent, respectively, to “asserting” or “deasserting” them as specified in Clause 22.

24.2.2 Functional requirements

The PCS comprises the Transmit, Receive, and Carrier Sense functions for 100BASE-T. In addition, the collisionDetect signal required by the MAC (COL on the MII) is derived from the PMA code-bit stream. The PCS shields the Reconciliation sublayer (and MAC) from the specific nature of the underlying channel. Specifically for receiving, the 100BASE-X PCS passes to the MII a sequence of data nibbles derived from incoming code-groups, each comprised of five code-bits, received from the medium. Code-group alignment and MAC packet delimiting is performed by embedding special non-data code-groups. The MII uses a nibble-wide, synchronous data path, with packet delimiting being provided by separate TX_EN and RX_DV signals. The PCS provides the functions necessary to map these two views of the exchanged data. The process is reversed for transmit.

The following provides a detailed specification of the functions performed by the PCS, which comprise five parallel processes (Transmit, Transmit Bits, Receive, Receive Bits, and Carrier Sense). Figure 24–4 includes a functional block diagram of the PCS.

The Receive Bits process accepts continuous code-bits via the PMA_UNITDATA.indicate primitive. Receive monitors these bits and generates RXD<3:0>, RX_DV, and RX_ER on the MII, and the internal flag, receiving, used by the Carrier Sense and Transmit processes.

Upon receiving proper code-groups via rx_code_bits from the link partner as described in 24.2.2.1.6, the Receive process may support the LPI function by deactivating all or part of receive functional blocks of the PCS, PMA, and PMD to conserve energy during the low link utilization period, and generate commands through the MII as described in 22.2.2.8. By interacting with the Link Monitor of the PMA, a link failure detection mechanism is included to differentiate two conditions of link failure due to signal off: the loss of channel signal during the normal operation and the loss of refresh signal in the LPI mode.

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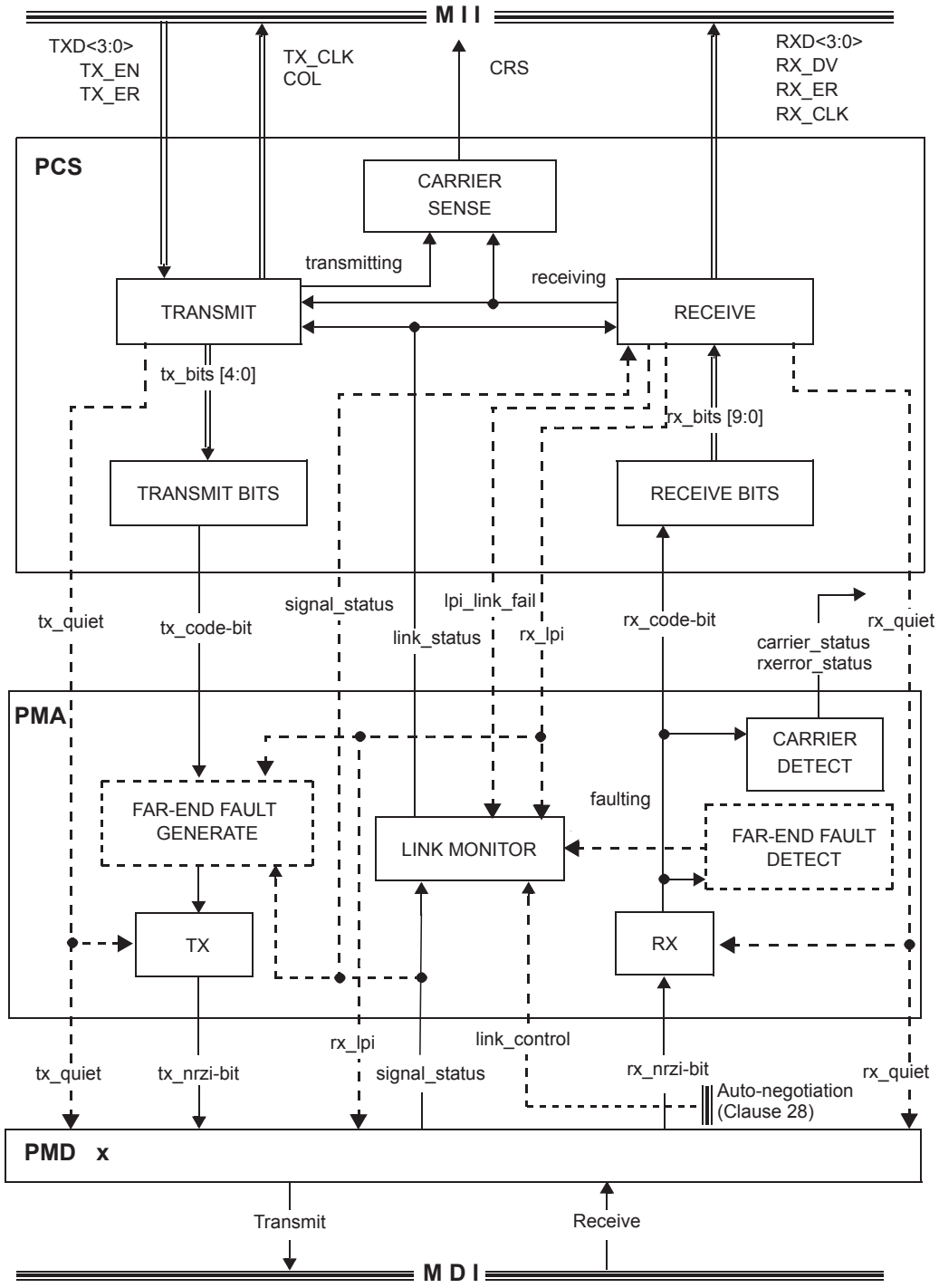

Figure 24–4—Functional block diagram

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The Transmit process generates continuous code-groups based upon the TXD<3:0>, TX_EN, and TX_ER signals on the MII. These code-groups are transmitted by Transmit Bits via the PMA_UNITDATA.request primitive. The Transmit process generates the MII signal COL based on whether a reception is occurring simultaneously with transmission. Additionally, it generates the internal flag, transmitting, for use by the Carrier Sense process.

The Transmit process may support the LPI function by deactivating all or part of the transmit functional blocks of the PCS, PMA, and PMD to conserve energy during the low link utilization period upon receiving the proper command from MII as described in 22.2.2.4. In this mode, the Transmit process is periodically activated to transmit refresh signal through tx_code_bits in order to allow the remote receiver to keep track of the long-term variation of channel characteristics and the clock drift between link partners.

The Carrier Sense process asserts the MII signal CRS when either transmitting or receiving is TRUE. Both the Transmit and Receive processes monitor link_status via the PMA_LINK.indicate primitive, to account for potential link failure conditions.

24.2.2.1 Code-groups

The PCS maps four-bit nibbles from the MII into five-bit code-groups, and vice versa, using a 4B/5B block coding scheme. A code-group is a consecutive sequence of five code-bits interpreted and mapped by the PCS. Implicit in the definition of a code-group is an establishment of code-group boundaries by an alignment function within the PCS Receive process. It is important to note that, with the sole exception of the SSD, which is used to achieve alignment, code-groups are undetectable and have no meaning outside the 100BASE-X physical protocol data unit, called a “stream.”

The coding method used, derived from ISO/IEC 9314-1, provides

a) Adequate codes (32) to provide for all Data code-groups (16) plus necessary control code-groups.
b) Appropriate coding efficiency (4 data bits per 5 code-bits; 80%) to effect a 100 Mb/s Physical Layer interface on a 125 Mb/s physical channel as provided by FDDI PMDs.
c) Sufficient transition density to facilitate clock recovery (when not scrambled).

Table 24–1 specifies the interpretation assigned to each five bit code-group, including the mapping to the nibble-wide (TXD or RXD) Data signals on the MII. The 32 code-groups are divided into four categories, as shown.

For clarity in the remainder of this clause, code-group names are shown between /slashes/. Code-group sequences are shown in succession, e.g., /1/2/....

The indicated code-group mapping is identical to ISO/IEC 9314-1:1989, with the following five exceptions:

a) The FDDI term *symbol* is avoided in order to prevent confusion with other 100BASE-T terminology. In general, the term *code-group* is used in its place.
b) The /S/ and /Q/ code-groups are not used by 100BASE-X and are interpreted as INVALID.
c) The /R/ code-group is used in 100BASE-X as the second code-group of the End-of-Stream delimiter rather than to indicate a Reset condition.
d) The /H/ code-group is used to propagate receive errors rather than to indicate the Halt Line State.
e) The /P/ code-group is used to indicate LPI.

24.2.2.1.1 Data code-groups

A Data code-group conveys one nibble of arbitrary data between the MII and the PCS. The sequence of Data code-groups is arbitrary, where any Data code-group can be followed by any other Data code-group. Data code-groups are coded and decoded but not interpreted by the PCS. Successful decoding of Data code-groups depends on proper receipt of the Start-of-Stream delimiter sequence, as defined in Table 24–1.

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Table 24–1—4B/5B code-groups

	PCS code-group [4:0] 4 3 2 1 0	Name	MII (TXD/RXD) <3:0> 3 2 1 0	Interpretation
DATA	1 1 1 1 0	0	0 0 0 0	Data 0
	0 1 0 0 1	1	0 0 0 1	Data 1
	1 0 1 0 0	2	0 0 1 0	Data 2
	1 0 1 0 1	3	0 0 1 1	Data 3
	0 1 0 1 0	4	0 1 0 0	Data 4
	0 1 0 1 1	5	0 1 0 1	Data 5
	0 1 1 1 0	6	0 1 1 0	Data 6
	0 1 1 1 1	7	0 1 1 1	Data 7
	1 0 0 1 0	8	1 0 0 0	Data 8
	1 0 0 1 1	9	1 0 0 1	Data 9
	1 0 1 1 0	A	1 0 1 0	Data A
	1 0 1 1 1	B	1 0 1 1	Data B
	1 1 0 1 0	C	1 1 0 0	Data C
	1 1 0 1 1	D	1 1 0 1	Data D
	1 1 1 0 0	E	1 1 1 0	Data E
	1 1 1 0 1	F	1 1 1 1	Data F
	1 1 1 1 1	I	undefined	IDLE; used as inter-stream fill code
	0 0 0 0 0	P	0 0 0 1	SLEEP; LPI code only for the EEE capability. Otherwise, Invalid code; refer to Table 22–1 and Table 22–2
CONTROL	1 1 0 0 0	J	0 1 0 1	Start-of-Stream Delimiter, Part 1 of 2; always used in pairs with K
	1 0 0 0 1	K	0 1 0 1	Start-of-Stream Delimiter, Part 2 of 2; always used in pairs with J
	0 1 1 0 1	T	undefined	End-of-Stream Delimiter, Part 1 of 2; always used in pairs with R
	0 0 1 1 1	R	undefined	End-of-Stream Delimiter, Part 2 of 2; always used in pairs with T
INVALID	0 0 1 0 0	H	Undefined	Transmit Error; used to force signaling errors
	0 0 0 0 0	V	Undefined	Invalid code
	0 0 0 0 1	V	Undefined	Invalid code
	0 0 0 1 0	V	Undefined	Invalid code
	0 0 0 1 1	V	Undefined	Invalid code
	0 0 1 0 1	V	Undefined	Invalid code
	0 0 1 1 0	V	Undefined	Invalid code
	0 1 0 0 0	V	Undefined	Invalid code
	0 1 1 0 0	V	Undefined	Invalid code
	1 0 0 0 0	V	Undefined	Invalid code
	1 1 0 0 1	V	Undefined	Invalid code

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24.2.2.1.2 Idle code-groups

The Idle code-group (/I/) is transferred between streams. It provides a continuous fill pattern to establish and maintain clock synchronization. Idle code-groups are emitted from, and interpreted by, the PCS.

24.2.2.1.3 Control code-groups

The Control code-groups are used in pairs (/J/K/, /T/R/) to delimit MAC packets. Control code-groups are emitted from, and interpreted by, the PCS.

24.2.2.1.4 Start-of-Stream delimiter (/J/K/)

A Start-of-Stream delimiter (SSD) is used to delineate the boundary of a data transmission sequence and to authenticate carrier events. The SSD is unique in that it may be recognized independently of previously established code-group boundaries. The Receive function within the PCS uses the SSD to establish code-group boundaries. A SSD consists of the sequence /J/K/.

On transmission, the first 8 bits of the MAC preamble are replaced by the SSD, a replacement that is reversed on reception.

24.2.2.1.5 End-of-Stream delimiter (/T/R/)

An End-of-Stream delimiter (ESD) terminates all normal data transmissions. Unlike the SSD, an ESD cannot be recognized independent of previously established code-group boundaries. An ESD consists of the sequence /T/R/.

24.2.2.1.6 SLEEP code-groups (/P/)

The SLEEP code-group (/P/) is used to delineate the boundary of an LPI sequence and to deliver a refresh signal to maintain clock synchronization and verify the link status. The SLEEP code-groups are emitted from, and interpreted by, the PCS.

24.2.2.1.7 Invalid code-groups

The /H/ code-group indicates that the PCS's client wishes to indicate a Transmit Error to its peer entity. The normal use of this indicator is for repeaters to propagate received errors. Transmit Error code-groups are emitted from the PCS, at the request of the PCS's client through the use of the TX_ER signal, as described in 24.2.4.2.

The presence of any invalid code-group on the medium, including /H/, denotes a collision artifact or an error condition. Invalid code-groups are not intentionally transmitted onto the medium by DTE's. The PCS indicates the reception of an Invalid code-group on the MII through the use of the RX_ER signal, as described in 24.2.4.4.

24.2.2.2 Encapsulation

The 100BASE-X PCS accepts frames from the MAC through the Reconciliation sublayer and MII. Due to the continuously signaled nature of the underlying PMA, and the encoding performed by the PCS, the 100BASE-X PCS encapsulates the MAC frame (100BASE-X Service Data Unit, SDU) into a Physical Layer stream (100BASE-X Protocol Data Unit, PDU).

Except for the two code-group SSD, data nibbles within the SDU (including the non-SSD portions of the MAC preamble and SFD) are not interpreted by the 100BASE-X PHY. The conversion from a MAC frame to a Physical Layer stream and back to a MAC frame is transparent to the MAC.

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Figure 24–5 depicts the mapping between MAC frames and Physical Layer streams.

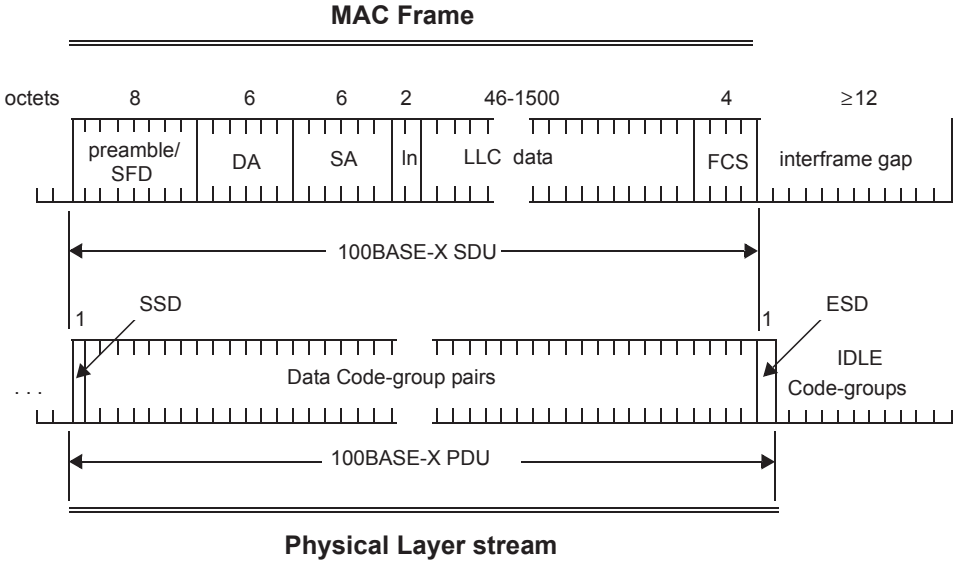

Figure 24–5—PCS encapsulation

A properly formed stream can be viewed as comprising the following three elements:

a) *Start-of-Stream Delimiter.* The start of a Physical Layer stream is indicated by a SSD, as defined in 24.2.2.1. The SSD replaces the first octet of the preamble from the MAC frame and vice versa.
b) *Data Code-groups*. Between delimiters (SSD and ESD), the PCS conveys Data code-groups corresponding to the data nibbles of the MII. These Data code-groups comprise the 100BASE-X Service Data Unit (SDU). Data nibbles within the SDU (including those corresponding to the MAC preamble and SFD) are not interpreted by the 100BASE-X PCS.
c) *End-of-Stream Delimiter.* The end of a properly formed stream is indicated by an ESD, as defined in 24.2.2.1. The ESD is transmitted by the PCS following the deassertion of TX_EN on the MII, which corresponds to the last data nibble composing the FCS from the MAC. It is transmitted during the period considered by the MAC to be the interframe gap (IFG). On reception, ESD is interpreted by the PCS as terminating the SDU.

Between streams, IDLE code-groups are conveyed between the PCS and PMA.

24.2.2.3 Data delay

The PCS maps a non-aligned code-bit data path from the PMA to an aligned, nibble-wide data path on the MII, both for Transmit and Receive. Logically, received bits must be buffered to facilitate SSD detection and alignment, coding translation, and ESD detection. These functions necessitate an internal PCS delay of at least two code-groups. In practice, alignment may necessitate even longer delays of the incoming code-bit stream.

When the MII is present as an exposed interface, the MII signals TX_CLK and RX_CLK, not depicted in the following state diagrams, shall be generated by the PCS in accordance with Clause 22.

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24.2.2.4 Mapping between MII and PMA

Figure 24–6 depicts the mapping of the nibble-wide data path of the MII to the five-bit-wide code-groups (internal to the PCS) and the code-bit path of the PMA interface.

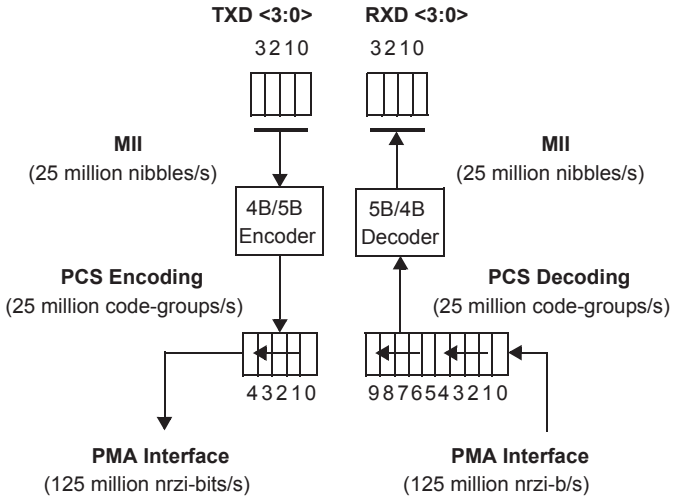

Figure 24–6—PCS reference diagram

Upon receipt of a nibble from the MII, the PCS encodes it into a five-bit code-group, according to 24.2.2.1. Code-groups are serialized into code-bits and passed to the PMA for transmission on the underlying medium, according to Figure 24–6. The first transmitted code-bit of a code-group is bit 4, and the last code-bit transmitted is bit 0. There is no numerical significance ascribed to the bits within a code-group; that is, the code-group is simply a five-bit pattern that has some predefined interpretation.

Similarly, the PCS deserializes code-bits received from the PMA, according to Figure 24–6. After alignment is achieved, based on SSD detection, the PCS converts code-groups into MII data nibbles, according to 24.2.2.1.

24.2.3 State variables

24.2.3.1 Constants

DATA

The set of 16 code-groups corresponding to valid DATA, as specified in 24.2.2.1. (In the Receive state diagram, the set operators $\in$ and $\notin$ are used to represent set membership and non-membership, respectively.)

ESD

The code-group pair corresponding to the End-of-Stream delimiter, as specified in 24.2.2.1.

ESD1

The code-group pair corresponding to the End-of-Stream delimiter, Part 1 (/T/), as specified in 24.2.2.1.

ESD2

The code-group pair corresponding to the End-of-Stream delimiter, Part 2 (/R/), as specified in

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24.2.2.1.

HALT
: The Transmit Error code-group (/H/), as specified in 24.2.2.1.

IDLE
: The IDLE code-group, as specified in 24.2.2.1.

IDLES
: A code-group pair comprised of /I/I/; /I/ as specified in 24.2.2.1.

SSD
: The code-group pair corresponding to the Start-of-Stream delimiter, as specified in 24.2.2.1.

SSD1
: The code-group corresponding to the Start-of-Stream delimiter, Part 1 (/J/), as specified in 24.2.2.1.

SSD2
: The code-group corresponding to the Start-of-Stream delimiter, Part 2 (/K/), as specified in 24.2.2.1.

The following constants are required only for the optional EEE capability:

SLEEP
: The SLEEP code-group (/P/) used by the LPI state delineator, as specified in 24.2.2.1.

TX_LP_IDLE
: A binary value 0001 of transmit nibble-wide Data signals (TXD), together with the deassertion of TX_EN and the assertion of TX_ER on the MII, used to indicate “Assert LPI”, as specified in 22.2.2.

RX_LP_IDLE
: A binary value 0001 of receive nibble-wide Data signals (RXD), together with the deassertion of RX_DV and the assertion of RX_ER on the MII, used to indicate “Assert LPI”, as specified in 22.2.2.

24.2.3.2 Variables

In the following, values for the MII parameters are definitively specified in Clause 22.

COL
: The COL signal of the MII as specified in Clause 22.

CRS
: The CRS signal of the MII as specified in Clause 22.

link_status
: The link_status parameter as communicated by the PMA_LINK.indicate primitive.

  Values: FAIL; the receive channel is not intact
  READY; the receive channel is intact and ready to be enabled by Auto-Negotiation
  OK; the receive channel is intact and enabled for reception

receiving
: A Boolean set by the Receive process to indicate non-IDLE activity (after squelch). Used by the Carrier Sense process, and also interpreted by the Transmit process for indicating a collision.

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Values: TRUE; unsquelched carrier being received
FALSE; carrier not being received

rx_bits [9:0]

A vector of the 10 most recently received code-bits from the PMA as assembled by Receive Bits and processed by Receive. rx_bits [0] is the most recently received (newest) code-bit; rx_bits [9] is the least recently received code-bit (oldest). When alignment has been achieved, it contains the last two code-groups.

rx_code-bit

The rx_code-bit parameter as communicated by the most recent PMA_UNITDATA.indicate primitive (that is, the value of the most recently received code-bit from the PMA).

RX_DV

The RX_DV signal of the MII as specified in Clause 22. Set by the Receive process, RX_DV is also interpreted by the Receive Bits process as an indication that rx_bits is code-group aligned.

RX_ER

The RX_ER signal of the MII as specified in Clause 22.

RXD <3:0>

The RXD <3:0> signal of the MII as specified in Clause 22.

transmitting

A Boolean set by the Transmit Process to indicate a transmission in progress. Used by the Carrier Sense process.

Values: TRUE; the PCS's client is transmitting
FALSE; the PCS's client is not transmitting

tx_bits [4:0]

A vector of code-bits representing a code-group prepared for transmission by the Transmit Process and transmitted to the PMA by the Transmit Bits process.

TX_EN

The TX_EN signal of the MII as specified in Clause 22.

TX_ER

The TX_ER signal of the MII as specified in Clause 22.

TXD <3:0>

The TXD <3:0> signal of the MII as specified in Clause 22.

The following variables are required only for the optional EEE capability:

lpi_link_fail

A Boolean set by the Receive process to control the transition to a Link Down state when in the LPI mode. Used by the Link Monitor process of the PMA as communicated through the PMA_LPILINKFAIL.request primitive.

Values: TRUE; local receiver has detected a link failure status when in the LPI mode
FALSE; local receiver is functioning normally when in the LPI mode

rx_lpi

A Boolean set by the Receive process to indicate the LPI mode. Used by the Link Monitor process of the PMA as communicated through the PMA_RXLPI.request primitive. This parameter is used to alter the signal detection time as shown in Table 25–3. It can also be used to halt the clock RXC of MII as described in Clause 22.

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Values: TRUE; local receiver is in the LPI mode
FALSE; local receiver is in the normal mode

rx_quiet

A Boolean set by the Receive process to indicate a Quiet state of the receiver in the LPI mode as communicated through the PMD_RXQUIET.request primitive. Also may be used to control the power-saving function of various receive blocks (PCS, PMA, and PMD).

Values: TRUE; the local receiver is in the Quiet state
FALSE; the local receiver is not in the Quiet state

tx_quiet

A Boolean set by the Transmit process to indicate a Quiet state of the transmitter in the LPI mode as communicated through the PMD_TXQUIET.request primitive. Also may be used to control the power-saving function of various transmit blocks (PCS, PMA, and PMD).

Values: TRUE; the local transmitter is in the Quiet state
FALSE; the local transmitter is not in the Quiet state

signal_status

The signal_status parameter as communicated by the PMD_SIGNAL.indicate primitive.

Values: ON; the quality and level of the received signal is satisfactory
OFF; the quality and level of the received signal is not satisfactory

24.2.3.3 Functions

nibble DECODE (code-group)

In Receive, this function takes as its argument a five-bit code-group and returns the corresponding MII RXD <3:0> nibble, per Table 24–1.

code-group ENCODE (nibble)

In the Transmit process, this function takes as its argument an MII TXD <3:0> nibble, and returns the corresponding five-bit code-group per Table 24–1.

SHIFTLEFT (rx_bits)

In Receive Bits, this function shifts rx_bits left one bit placing rx_bits [8] in rx_bits [9], rx_bits [7] in rx_bits [8] and so on until rx_bits [1] gets rx_bits [0].

24.2.3.4 Timers

code-bit_timer

In the Transmit Bits process, the timer governing the output of code-bits from the PCS to the PMA and thereby to the medium with a nominal 8 ns period. This timer shall be derived from a fixed frequency oscillator with a base frequency of 125 MHz ± 0.005% and phase jitter above 20 kHz less than ± 8°.

The following timers are required only for the optional EEE capability:

lpi_link_fail_timer

In the LPI mode, the receiver in Wake state is checking if valid symbols are properly received. This timer defines the maximum time allowed for the PHY between entry into the Wake state and subsequent entry into the Quiet, Sleep, or Idle states before assuming a link failure. The timer shall have a period between 90 μs and 110 μs.

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lpi_rx_ti_timer

In the LPI mode, the receiver can move to the Idle state when it receives consecutive IDLE symbols. In order to distinguish the intended IDLE symbols sent by the link partner from ones falsely decoded during the transition from the Sleep state to the Quiet state before the signal status is deasserted, this receiver timer counts the minimum duration of received IDLE symbols. During this period of time, the receiver stays in an intermediate state. The timer shall have a period between 0.8 μs and 0.9 μs.

lpi_rx_tq_timer

In the LPI mode, this receiver timer counts the maximum duration the PHY stays in the Quiet state before it expects a Refresh signal. If the PHY fails to receive a valid Refresh signal or Wake signal before this timer expires, the receiver shall assume a link failure. The timer shall have a period between 24 ms and 26 ms.

lpi_rx_ts_timer

In the LPI mode, this receiver timer counts the maximum duration the PHY is allowed to stay in the Sleep state before assuming a link failure. The timer shall have a period between 240 μs and 260 μs.

lpi_rx_tw_timer

In the LPI mode, the receiver in the Quiet state is woken up by the receiving signal. This receiver timer counts the expected duration for the PHY to identify if valid SLEEP symbols for the Refresh state or valid IDLES for the Wake state have been properly received. If none of the SLEEP or IDLE symbols are received when the timer expires, the wake error counter as defined in MDIO manageable device (MMD) register 3.22 (see 45.2.3.10) shall be incremented. The timer shall have a period that does not exceed 20.5 μs.

lpi_tx_tq_timer

In the LPI mode, this transmitter timer counts the duration the PHY remains in the Quiet state before it must wake to send a refresh signal. The timer shall have a period between 20 ms and 22 ms.

lpi_tx_ts_timer

In the LPI mode, this transmitter timer counts the duration the PHY is sending continuous SLEEP symbols in the Sleep state before going into the Quiet state. The timer shall have a period between 200 μs and 220 μs.

24.2.3.5 Messages

gotCodeGroup.indicate

A signal sent to the Receive process by the Receive Bits process after alignment has been achieved signifying completion of reception of the next code-group in rx_bits(4:0), with the preceding code-group moved to rx_bits [9:5]. rx_bits [9:5] may be considered as the “current” code-group.

PMA_UNITDATA.indicate (rx_code-bit)

A signal sent by the PMA signifying that the next code-bit from the medium is available in rx_code-bit.

sentCodeGroup.indicate

A signal sent to the Transmit process from the Transmit Bits process signifying the completion of

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transmission of the code-group in tx_bits [4:0].

24.2.4 State diagrams

24.2.4.1 Transmit Bits

Transmit Bits is responsible for taking code-groups prepared by the Transmit process and transmitting them to the PMA using PMA_UNITDATA.request, the frequency of which determines the transmit clock. Transmit deposits these code-groups in tx_bits with Transmit Bits signaling completion of a code-group transmission with sentCodeGroup.indicate.

The PCS shall implement the Transmit Bits process as depicted in Figure 24–7 including compliance with the associated state variables as specified in 24.2.3.

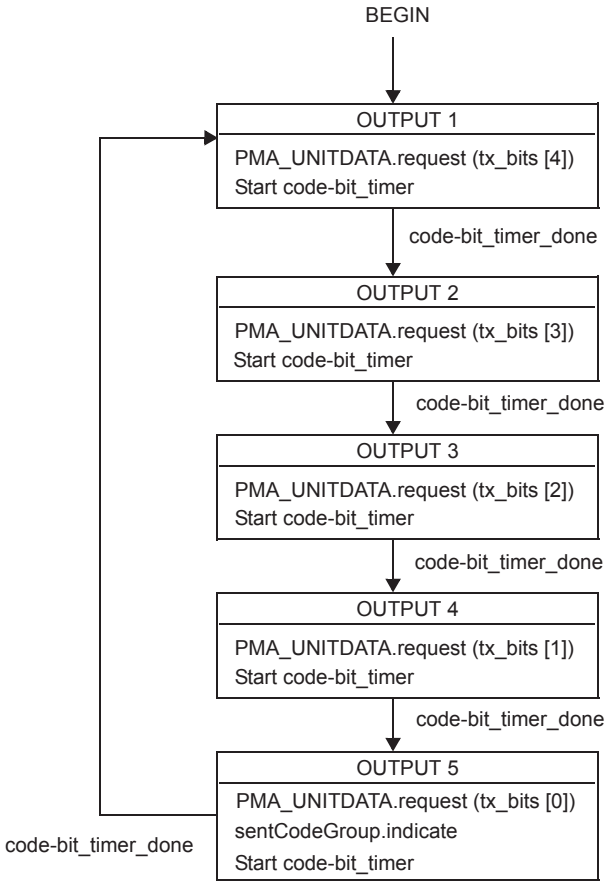

Figure 24–7—Transmit Bits state diagram

24.2.4.2 Transmit

The Transmit process sends code-groups to the PMA via tx_bits and the Transmit Bits process. When initially invoked, and between streams (delimited by TX_EN on the MII), except in the LPI mode for the optional EEE capability, the Transmit process sources continuous Idle code-groups (/I/) to the PMA. Upon the assertion of TX_EN by the MII, the Transmit process passes an SSD (/J/K/) to the PMA, ignoring the TXD<3:0> nibbles during these two code-group times. Following the SSD, each TXD<3:0> nibble is encoded into a five-bit code-group until TX_EN is deasserted. If, while TX_EN is asserted, the TX_ER signal is asserted, the Transmit process passes Transmit Error code-groups (/H/) to the PMA. Following the

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deassertion of TX_EN, an ESD (/T/R/) is generated, after which the transmission of Idle code-groups is resumed by the IDLE state.

If EEE Capability is supported, upon the assertion of LPI on the MII (a binary value 0001 of TXD, together with the deassertion of TX_EN and the assertion of TX_ER, see 22.2.2), the Transmit process enters the LPI mode and starts to source SLEEP (/P/) code-groups to the PMA. In the LPI mode, the Transmit process is controlled by timers to switch between the TX_SLEEP and TX_QUIET states. The Transmit process returns to the IDLE state whenever the MII deasserts LPI.

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 causes an immediate transition to the IDLE state and supersedes any other Transmit process operations.

The PCS shall implement the Transmit process as depicted in Figure 24–8 including compliance with the associated state variables as specified in 24.2.3.

24.2.4.3 Receive Bits

The Receive Bits process collects code-bits from the PMA interface passing them to the Receive process via rx_bits. rx_bits [9:0] represents a sliding, 10-bit window on the PMA code-bits, with newly received code-bits from the PMA (rx_code-bit) being shifted into rx_bits [0]. This is depicted in Figure 24–9. Bits are collected serially until Receive indicates alignment by asserting RX_DV, after which Receive Bits signals Receive for every five code-bits accumulated. Serial processing resumes with the deassertion of RX_DV.

The PCS shall implement the Receive Bits process as depicted in Figure 24–10 including compliance with the associated state variables as specified in 24.2.3.

24.2.4.4 Receive

The Receive process state diagram can be viewed as comprising two sections: prealigned and aligned. In the prealigned states, IDLE, CARRIER DETECT, and IDENTIFY JK, except for the detection of SLEEP code-groups when supporting the optional EEE capability, the Receive process is waiting for an indication of channel activity followed by an SSD. After successful alignment, the incoming code-groups are decoded while waiting for stream termination.

If EEE Capability is supported, when the Receive process successfully aligns and decodes two consecutive SLEEP (/P/) code-groups, it enters the LPI mode and stays in LPI states until either the IDLE code-groups are received, where it leads the Receive process to the IDLE state, or a link failure condition in the LPI mode occurs, where it causes the Receive process to enter the RX_LPI_LINK_FAIL state and eventually move to the IDLE state.

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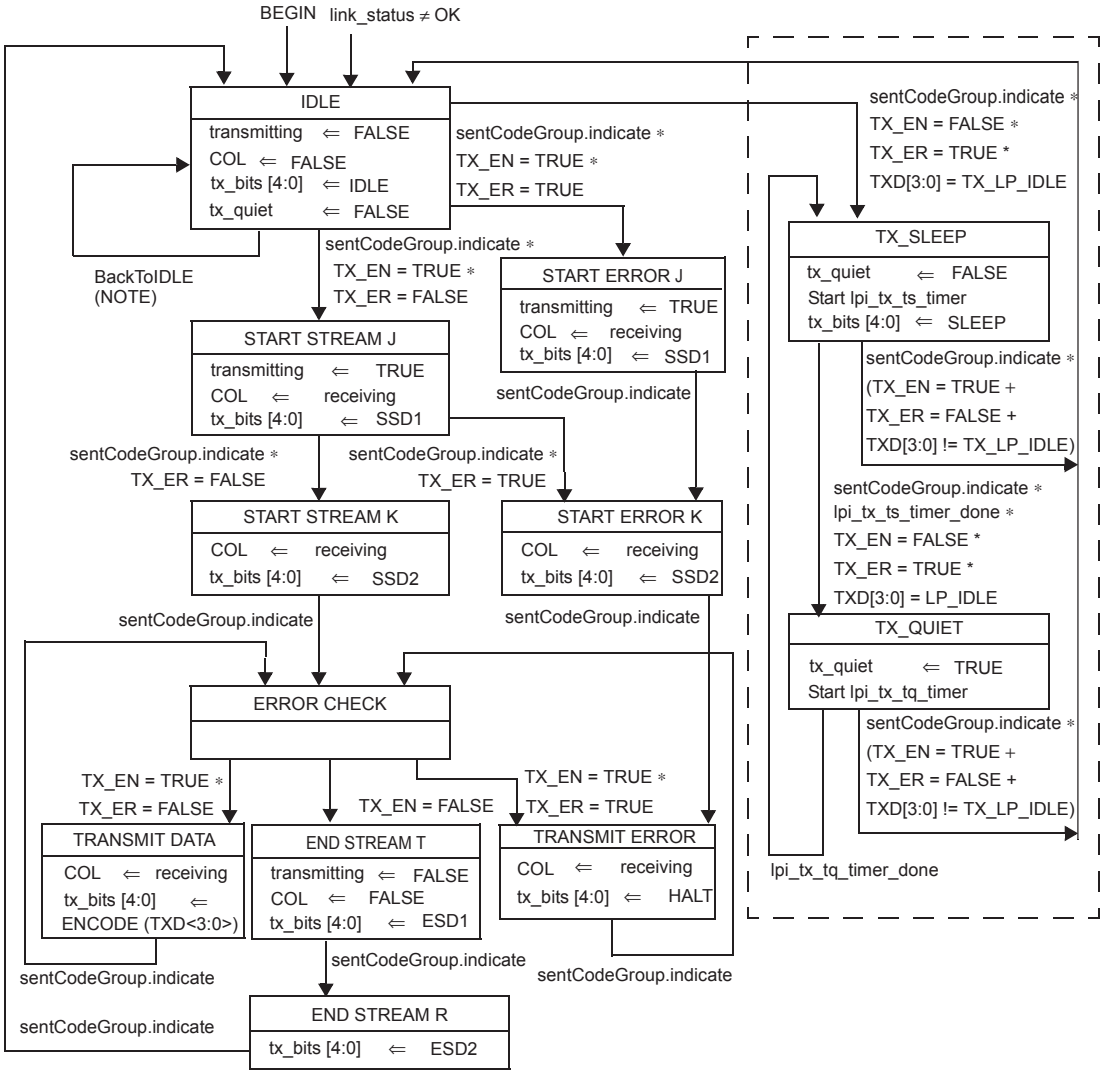

NOTE 1—BackToIDLE represents the following branch condition:

If the EEE capability is supported,
sentCodeGroup.indicate * TX_EN = FALSE * (TX_E R= FALSE + (TX_ER = TRUE * TXD[3:0] ≠ TX_LP_IDLE))
Otherwise,
sentCodeGroup.indicate * TX_EN = FALSE

NOTE 2—States and state transitions shown within the dashed box are only required for the EEE capability

Figure 24–8—Transmit state diagram

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24.2.4.4.1 Detecting channel activity

In a DTE operating in half duplex mode, the detection of activity on the underlying channel is used both by the MAC (via the MII CRS signal and the Reconciliation sublayer) for deferral purposes, and by the Transmit process for collision detection. Activity, signaled by the assertion of receiving, is indicated by the receipt of two non-contiguous ZEROS within any 10 code-bits of the incoming code-bit stream.

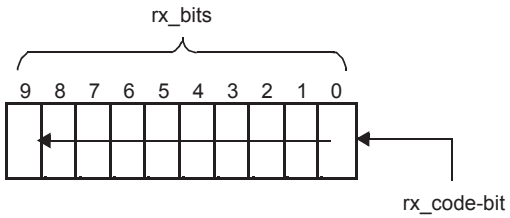

Figure 24–9—Receive Bits reference diagram

24.2.4.4.2 Code-group alignment

After channel activity is detected, the Receive process first aligns the incoming code-bits on code-group boundaries for subsequent data decoding. This is achieved by scanning the rx_bits vector for a SSD (/J/K/). The MII RX_DV signal remains deasserted during this time, which ensures that the Reconciliation sublayer will ignore any signals on RXD <3:0>. Detection of the SSD causes the Receive process to enter the START OF STREAM J state.

Well-formed streams contain SSD (/J/K/) in place of the first eight preamble bits. In the event that something else is sensed immediately following detection of carrier, a False Carrier Indication is signaled to the MII by asserting RX_ER and setting RXD to 1110 while RX_DV remains deasserted. The associated carrier event, as terminated by 10 ONEs, is otherwise ignored.

24.2.4.4.3 Stream decoding

The Receive process substitutes a sequence of alternating ONE and ZERO data-bits for the SSD, which is consistent with the preamble pattern expected by the MAC.

The Receive process then performs the DECODE function on the incoming code-groups, passing decoded data to the MII, including those corresponding to the remainder of the MAC preamble and SFD. The MII signal RX_ER is asserted upon decoding any code-group following the SSD that is neither a valid Data code-group nor a valid stream termination sequence.

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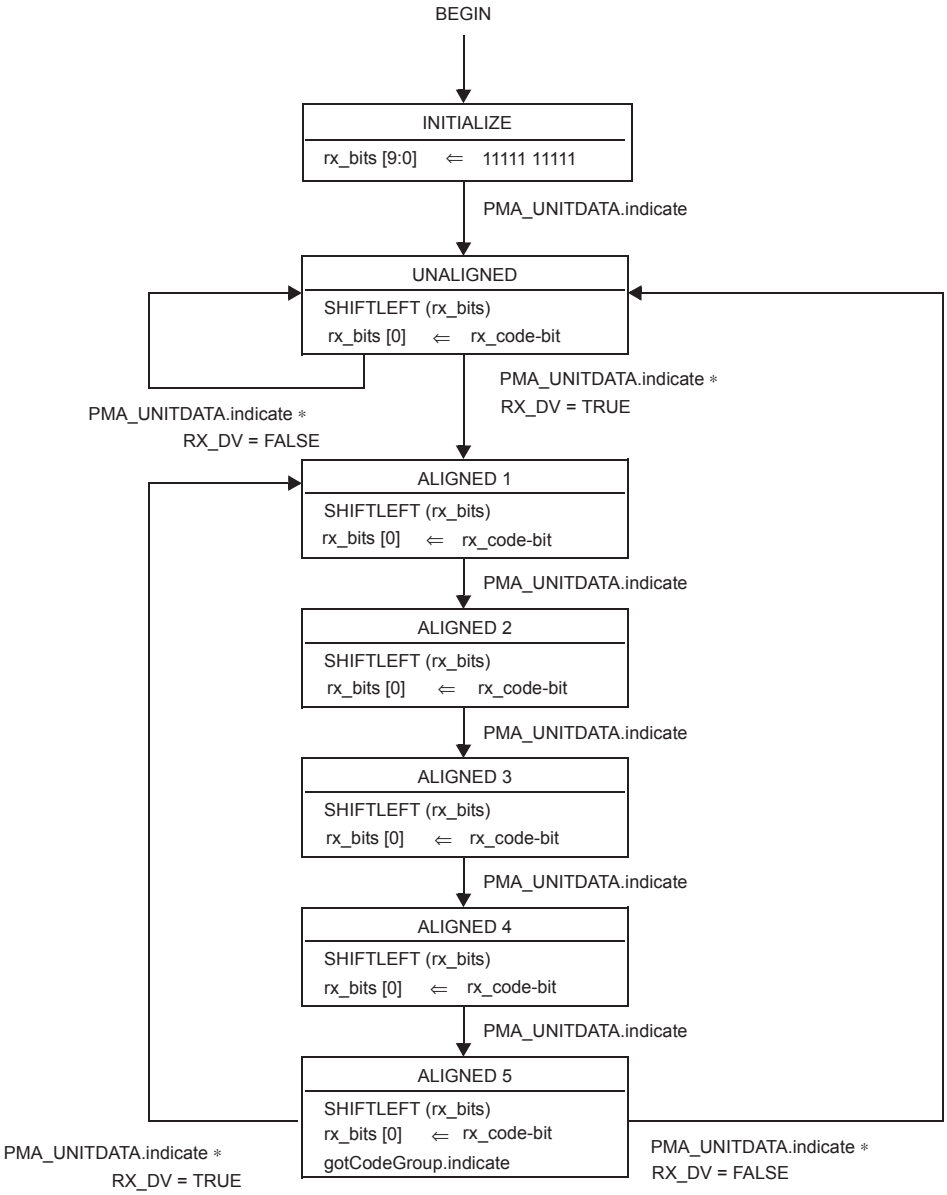

Figure 24–10—Receive Bits state diagram

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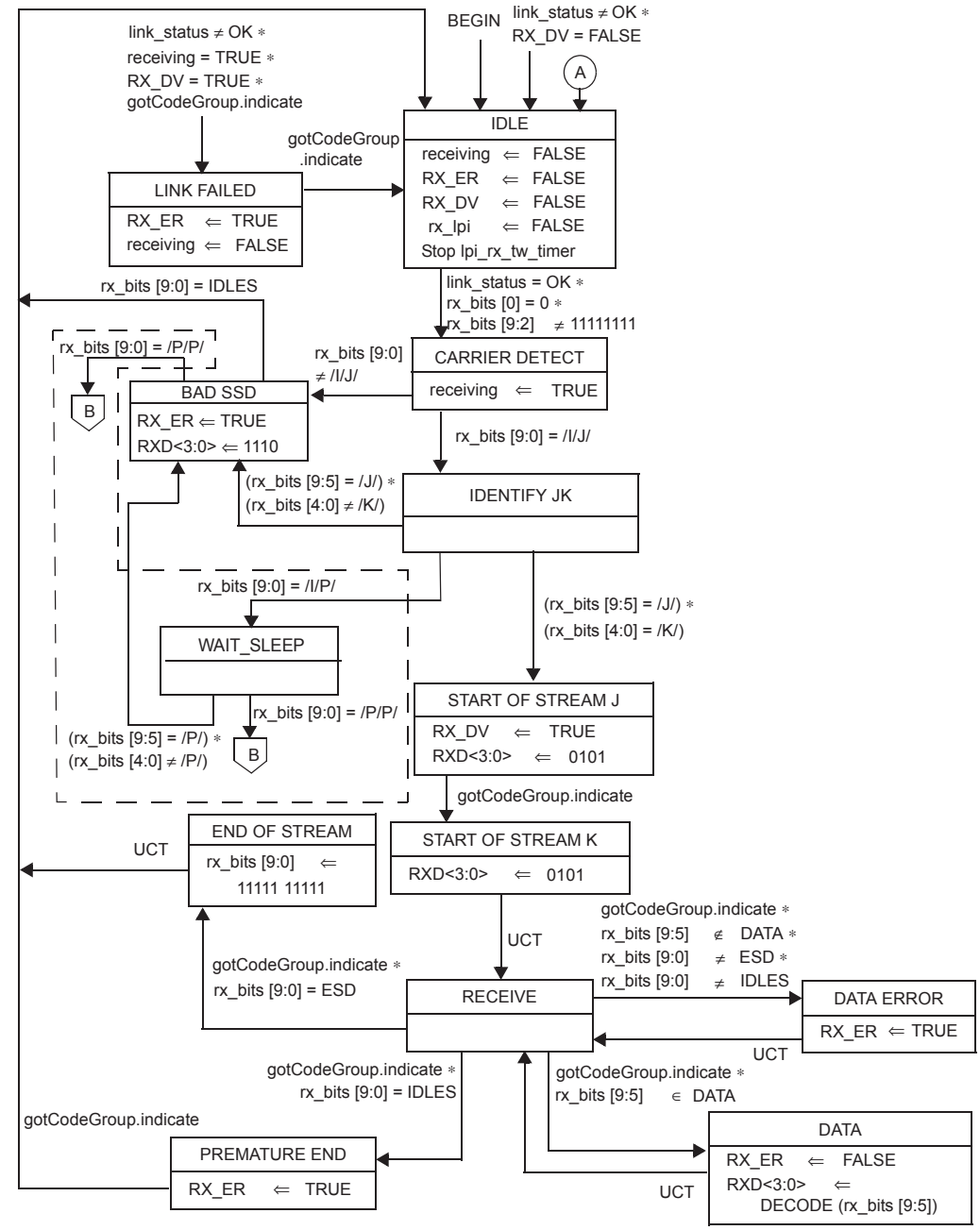
24.2.4.4.4 Stream termination

There are two means of effecting stream termination in the Receive process (Figure 24–11 and Figure 24–12) .



NOTE—States and state transitions shown within the dashed box are only required for the EEE capability

Figure 24–11—Receive state diagram, part a

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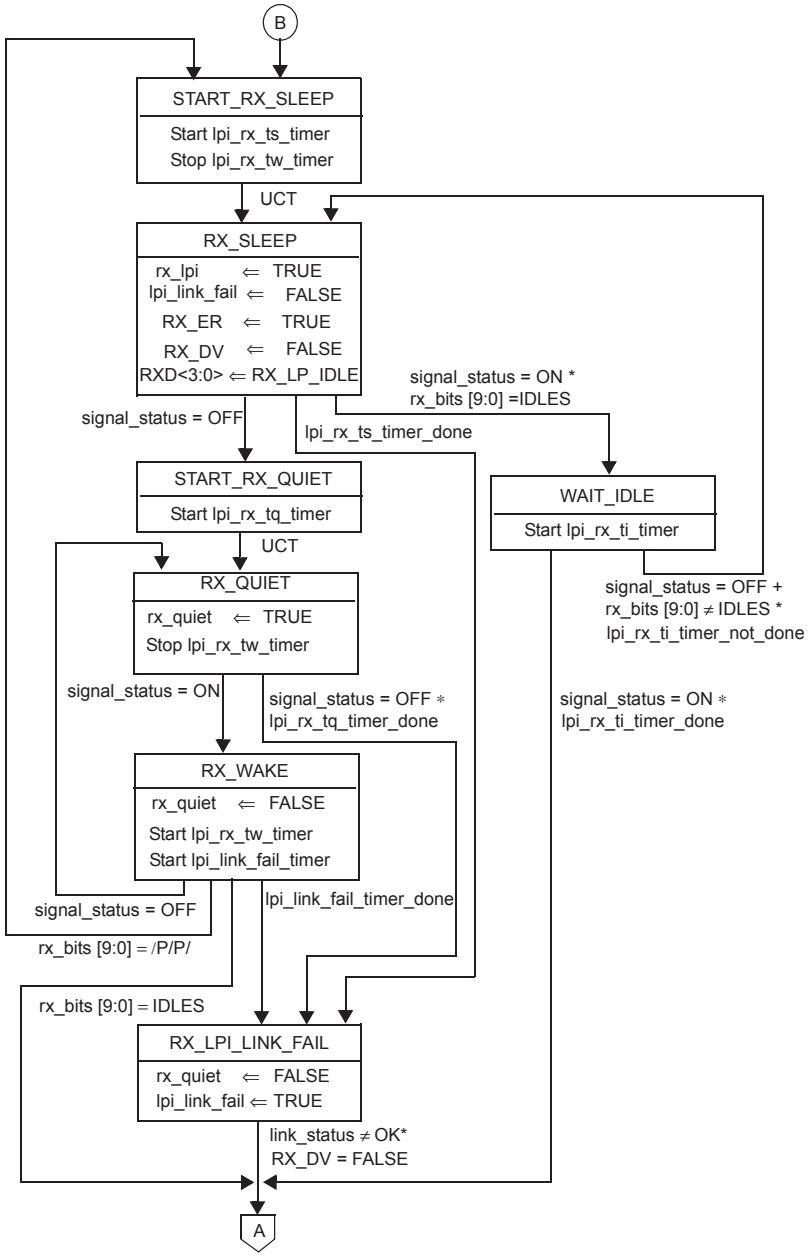

Figure 24–12—Receive state diagram, part b (only required for the EEE capability)

A normal stream termination is caused by detection of an ESD (/T/R/) in the rx_bits vector. In order to preserve the ability of the MAC to properly delimit the FCS at the end of the frame (that is, to avoid incorrect AlignmentErrors in the MAC) the internal signal receiving (and through it, the MII CRS signal, per Clause 22) is deasserted immediately following the last code-bit in the stream that maps to the FCS. Note that the condition link_status ≠ OK during stream reception (that is, when receiving = TRUE) causes an immediate transition to the LINK FAILED state and supersedes any other Receive process operations.

A premature stream termination is caused by the detection of two Idle code-groups (/I/I) in the rx_bits vector prior to an ESD. Note that RX_DV remains asserted during the nibble corresponding to the first five

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contiguous ONEs while RX_ER is signaled on the MII. RX_ER is also asserted in the LINK FAILED state, which ensures that RX_ER remains asserted for sufficient time to be detected.

Stream termination causes a transition to the IDLE state.

The PCS shall implement the Receive process as depicted in Figure 24–11 and Figure 24–12 including compliance with the associated state variables as specified in 24.2.3.

24.2.4.5 Carrier Sense

The Carrier Sense process generates the signal CRS on the MII, which (via the Reconciliation sublayer) a MAC operating in half duplex mode uses for deferral. The process operates by performing a logical OR operation on the internal messages receiving and transmitting, generated by the Receive and Transmit processes, respectively.

The PCS shall implement the Carrier Sense process as depicted in Figure 24–13 including compliance with the associated state variables as specified in 24.2.3.

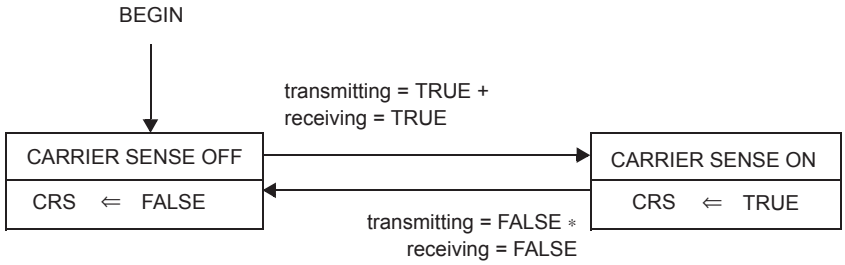

Figure 24–13—Carrier Sense state diagram

24.3 Physical Medium Attachment (PMA) sublayer

24.3.1 Service interface

The following specifies the service interface provided by the PMA to the PCS or another client, such as a repeater. These services are described in an abstract manner and do not imply any particular implementation.

The PMA Service Interface supports the exchange of code-bits between the PCS and/or Repeater entities. The PMA converts code-bits into NRZI format and passes these to the PMD, and vice versa. It also generates additional status indications for use by its client.

The following primitives are defined:

PMA_TYPE.indicate

PMA_UNITDATA.request

PMA_UNITDATA.indicate

PMA_CARRIER.indicate

PMA_LINK.indicate

PMA_LINK.request

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PMA_RXERROR.indicate

PMA_LPILINKFAIL.request

PMA_RXLPI.request

24.3.1.1 PMA_TYPE.indicate

This primitive is generated by the PMA to indicate the nature of the PMA instantiation. The purpose of this primitive is to allow clients to support connections to the various types of 100BASE-T PMA entities in a generalized manner.

24.3.1.1.1 Semantics of the service primitive

PMA_TYPE.indicate (pma_type)

The pma_type parameter for use with a 100BASE-X PMA is “X”.

24.3.1.1.2 When generated

The PMA continuously generates this primitive to indicate the value of pma_type.

24.3.1.1.3 Effect of receipt

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

24.3.1.2 PMA_UNITDATA.request

This primitive defines the transfer of data (in the form of code-bits) from the PMA’s client to the PMA.

24.3.1.2.1 Semantics of the service primitive

PMA_UNITDATA.request (tx_code-bit)

This primitive defines the transfer of data (in the form of code-bits) from the PCS or other client to the PMA. The tx_code-bit parameter can take one of two values: ONE or ZERO.

24.3.1.2.2 When generated

The PCS or other client continuously sends, at a nominal 125 Mb/s rate, the appropriate code-bit for transmission on the medium.

24.3.1.2.3 Effect of receipt

Upon receipt of this primitive, the PMA generates a PMD_UNITDATA.request primitive, requesting transmission of the indicated code-bit, in NRZI format (tx_nrzi-bit), on the MDI.

24.3.1.3 PMA_UNITDATA.indicate

This primitive defines the transfer of data (in the form of code-bits) from the PMA to the PCS or other client.

24.3.1.3.1 Semantics of the service primitive

PMA_UNITDATA.indicate (rx_code-bit)

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The data conveyed by PMA_UNITDATA.indicate is a continuous code-bit sequence at a nominal 125 Mb/s rate. The rx_code-bit parameter can take one of two values: ONE or ZERO.

24.3.1.3.2 When generated

The PMA continuously sends code-bits to the PCS or other client corresponding to the PMD_UNITDATA.indicate primitives received from the PMD.

24.3.1.3.3 Effect of receipt

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

24.3.1.4 PMA_CARRIER.indicate

This primitive is generated by the PMA to indicate that a non-squelched, non-IDLE code-bit sequence is being received from the PMD. The purpose of this primitive is to give clients the earliest reliable indication of activity on the underlying continuous-signaling channel.

24.3.1.4.1 Semantics of the service primitive

PMA_CARRIER.indicate (carrier_status)

The carrier_status parameter can take on one of two values, ON or OFF, indicating whether a non-squelched, non-IDLE code-bit sequence (that is, carrier) is being received (ON) or not (OFF).

24.3.1.4.2 When generated

The PMA generates this primitive to indicate a change in the value of carrier_status.

24.3.1.4.3 Effect of receipt

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

24.3.1.5 PMA_LINK.indicate

This primitive is generated by the PMA to indicate the status of the underlying PMD receive link.

24.3.1.5.1 Semantics of the service primitive

PMA_LINK.indicate (link_status)

The link_status parameter can take on one of three values: READY, OK, or FAIL, indicating whether the underlying receive channel is intact and ready to be enabled by Auto-Negotiation (READY), intact and enabled (OK), or not intact (FAIL). Link_status is set to FAIL when the PMD sets signal_status to OFF; when Auto-Negotiation (optional) sets link_control to DISABLE; or when Far-End Fault Detect (optional) sets faulting to TRUE. When link_status ≠ OK, then rx_code-bit and carrier_status are undefined.

24.3.1.5.2 When generated

The PMA generates this primitive to indicate a change in the value of link_status.

24.3.1.5.3 Effect of receipt

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

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24.3.1.6 PMA_LINK.request

This primitive is generated by the Auto-Negotiation algorithm, when implemented, to allow it to enable and disable operation of the PMA. See Clause 28. When Auto-Negotiation is not implemented, the primitive is never invoked and the PMA behaves as if link_control = ENABLE.

24.3.1.6.1 Semantics of the service primitive

PMA_LINK.request (link_control)

The link_control parameter takes on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE. Auto-Negotiation sets link_control to SCAN_FOR_CARRIER prior to receiving any fast link pulses, permitting the PMA to sense a 100BASE-X signal. Auto-Negotiation sets link_control to DISABLE when it senses an Auto-Negotiation partner (fast link pulses) and must temporarily disable the 100BASE-X PHY while negotiation ensues. Auto-Negotiation sets link_control to ENABLE when full control is passed to the 100BASE-X PHY.

24.3.1.6.2 When generated

Auto-Negotiation generates this primitive to indicate a change in link_control as described in Clause 28.

24.3.1.6.3 Effect of receipt

This primitive affects operation of the PMA Link Monitor function as described in 24.3.4.4.

24.3.1.7 PMA_RXERROR.indicate

This primitive is generated by the PMA to indicate that an error has been detected during a carrier event.

24.3.1.7.1 Semantics of the service primitive

PMA_RXERROR.indicate (rxerror_status)

The rxerror_status parameter can take on one of two values: ERROR or NO_ERROR, indicating whether the received carrier event contains a detectable error (ERROR) or not (NO_ERROR). A carrier event is considered to be in error when it is not started by a Start-of-Stream Delimiter.

24.3.1.7.2 When generated

The PMA generates this primitive whenever a new, non-squelched carrier event is not started by a Start-of-Stream Delimiter.

24.3.1.7.3 Effect of receipt

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

24.3.1.8 PMA_LPILINKFAIL.request

This primitive is generated by the Receive Process of the PCS only if EEE is supported to control one of the link failure conditions of the Link Monitor in the PMA (see 24.2.4.3 and Figure 24–12).

24.3.1.8.1 Semantics of the service primitive

PMA_LPILINKFAIL.request (lpi_link_fail)

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The lpi_link_fail parameter takes on one of two values, TRUE or FALSE, indicating whether a link failure condition has been set (TRUE) or not (FALSE). The value of TRUE, when in the LPI mode, sets the link_status of the Link Monitor to FAIL (see 24.3.4.4 and Figure 24–15).

24.3.1.8.2 When generated

The PCS generates this primitive to indicate a link failure condition caused by the loss of Refresh signal when in the LPI mode.

24.3.1.8.3 Effect of receipt

This primitive affects operation of the PMA Link Monitor function as described in 24.3.4.4.

24.3.1.9 PMA_RXLPI.request

This primitive is generated by the Receive Process of the PCS only if EEE is supported to indicate that the receiver is in the LPI mode (see 24.2.4.3 and Figure 24–12).

24.3.1.9.1 Semantics of the service primitive

PMA_RXLPI.request (rx_lpi)

The rx_lpi parameter takes on one of two values, TRUE or FALSE, indicating whether the receiver is in the LPI mode (TRUE) or not (FALSE).

24.3.1.9.2 When generated

The PCS generates this primitive to indicate the LPI mode.

24.3.1.9.3 Effect of receipt

This primitive affects the operation of the PMA Link Monitor function as described in 24.3.4.4. Other use of receipt of this primitive by the client is unspecified by the PMA sublayer.

24.3.2 Functional requirements

The 100BASE-X PMA comprises the following functions:

a) Mapping of transmit and receive code-bits between the PMA Service Interface and the PMD Service Interface.
b) Link Monitor, which maps the PMD_SIGNAL.indicate primitive to the PMA_LINK.indicate primitive, indicating the availability of the underlying PMD.
c) Carrier Detection, which generates the PMA_CARRIER.indicate and PMA_RXERROR.indicate primitives from inspection of received PMD signals.
d) Far-End Fault (optional), comprised of the Far-End Fault Generate and Far-End Fault Detect processes, which sense receive channel failures and send the Far-End Fault Indication, and sense the Far-End Fault Indication.
e) EEE capability, which disables the Far-End Fault function and modifies the link down condition with the PMA_RXLPI.request primitive.

Figure 24–4 includes a functional block diagram of the PMA.

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24.3.2.1 Far-End fault

Auto-Negotiation provides a Remote Fault capability useful for detection of asymmetric link failures; i.e., channel error conditions detected by the far-end station but not the near-end station. Since Auto-Negotiation is specified only for media supporting eight-pin modular connectors, such as used by 100BASE-TX over twisted pair, Auto-Negotiation's Remote Fault capability is unavailable to other media for which it may be functionally beneficial, such as 100BASE-TX over shielded twisted pair or 100BASE-FX. A remote fault capability for 100BASE-FX is particularly useful due to this medium's applicability over longer distances (making end-station checking inconvenient) and for backbones (in which detection of link failures can trigger redundant systems).

For these reasons, 100BASE-X provides an optional Far-End Fault facility when Auto-Negotiation cannot be used. Far-End Fault shall not be implemented for media capable of supporting Auto-Negotiation.

When no signal is being received, as indicated by the PMD's signal detect function, the Far-End Fault feature permits the station to transmit a special Far-End Fault Indication to its far-end peer. The Far-End Fault Indication is sent only when a physical error condition is sensed on the receive channel. In all other situations, including reception of the Far-End Fault Indication itself, the PMA passes through tx_code-bit. (Note that the Far-End Fault architecture is such that IDLEs are automatically transmitted when the Far-End Fault Indication is detected. This is necessary to re-establish communication when the link is repaired.)

The Far-End Fault Indication is comprised of three or more repeating cycles, each of 84 ONEs followed by a single ZERO. This signal is sent in-band and is readily detectable but is constructed so as to not satisfy the 100BASE-X carrier sense criterion. It is therefore transparent to the PMA's client and to stations not implementing Far-End Fault.

As shown in Figure 24–4, Far-End Fault is implemented through the Far-End Fault Generate, Far-End Fault Detect, and the Link Monitor processes.

The Far-End Fault Generate process, which is interposed between the incoming tx_code-bit stream and the TX process, is responsible for sensing a receive channel failure (signal_status=OFF during the normal operation) and transmitting the Far-End Fault Indication in response. The transmission of the Far-End Fault Indication may start or stop at any time depending only on signal_status. The Far-End Fault shall not be generated when in the LPI mode.

The Far-End Fault Detect process continuously monitors rx_code-bits from the RX process for the Far-End Fault Indication. Detection of the Far-End Fault Indication disables the station by causing the Link Monitor process to deassert link_status, which in turn causes the station to source IDLEs. Far-End Fault detection can also be used by management functions not specified in this clause.

24.3.2.2 Comparison to previous IEEE 802.3 PMAs

Previous IEEE 802.3 PMAs perform the additional functions of SQE Test and Jabber. Neither of these functions is implemented in the 100BASE-X PMA.

SQE Test is provided in other Physical Layers to check the integrity of the Collision Detection mechanism independently of the Transmit and Receive capabilities of the Physical Layer. Since 100BASE-X effects collision detection by sensing receptions that occur during transmissions, collision detection is dependent on the health of the receive channel. By checking the ability to properly receive signals from the PMD, the Link Monitor function therefore functionally subsumes the functions previously implemented by SQE Test.

The Jabber function prevents a DTE from causing total network failure under certain classes of faults. When using mixing media (e.g., coaxial cables or passive optical star couplers), this function must naturally be implemented in the DTE. 100BASE-X requires the use of an active repeater, with one DTE or repeater

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attached to each port. As an implementation optimization, the Jabber function has therefore been moved to the repeater in 100BASE-X.

24.3.2.3 EEE capability

EEE capability, when communicated by the PMA_RXLPI.request primitive, affects the PMA in two ways. It disables the operation of the Far-End Fault processes to ignore the frequent on and off activity of signal_status. It receives link failure detection as communicated by the PMA_LPILINKFAIL.request primitive and changes the Link Monitor process to allow an exit from the LPI mode to a link down state. The EEE capability of the PMA is required only if the PCS supports EEE. If LPI is implemented, the operation of the PMA shall comply with the requirements in this subclause.

24.3.3 State variables

24.3.3.1 Constants

FEF_CYCLES

The number of consecutive cycles (of FEF_ONES ONEs and a single ZERO) necessary to indicate the Far-End Fault Indication. This value is 3.

FEF_ONES

The number of consecutive ONEs to be transmitted for each cycle of the Far-End Fault Indication. This value is 84.

24.3.3.2 Variables

carrier_status

The carrier_status parameter to be communicated by the Carrier Detect process through the PMA_CARRIER.indicate primitive. Carrier is defined as receipt of two noncontiguous ZEROs in 10 code-bits.

Values: ON; carrier is being received
OFF; carrier is not being received

faulting

The faulting variable set by the Far-End Fault Detect process, when implemented, indicating whether or not a Far-End Fault Indication is being sensed. This variable is used by the Link Monitor process to force link_status to FAIL.When Far-End Fault is not implemented, this variable is always FALSE.

Values: TRUE; Far-End Fault Indication is being sensed
FALSE; Far-End Fault Indication is not being sensed

link_control

The link_control parameter as communicated by the PMA_LINK.request primitive. When Auto-Negotiation is not implemented, the value of link_control is always ENABLE. See Clause 28 for a complete definition.

link_status

The link_status parameter as communicated by the Link Monitor process through the PMA_LINK.indicate primitive.

Values: FAIL; the receive channel is not intact

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READY; the receive channel is intact and ready to be enabled by Auto-Negotiation
OK; the receive channel is intact and enabled for reception

r_bits [9:0]

In Carrier Detect, a vector of the 10 most recently received code-bits from the PMD RX process. r_bits [0] is the most recently received (newest) code-bit; r_bits [9] is the least recently received code-bit (oldest). r_bits is an internal variable used exclusively by the Carrier Detect process.

rx_code-bit

The rx_code-bit parameter as delivered by the RX process, which operates in synchronism with the PMD_UNITDATA.indicate primitive. rx_code-bit is the most recently received code-bit from the PMD after conversion from NRZI.

rxerror_status

The rxerror_status parameter to be communicated by the Carrier Detect process through the PMA_RXERROR.indicate primitive.

Values: NO_ERROR; no error detected in the carrier event being received
ERROR; the carrier event being received is in error

signal_status

The signal_status parameter as communicated by the PMD_SIGNAL.indicate primitive.

Values: ON; the quality and level of the received signal is satisfactory
OFF; the quality and level of the received signal is not satisfactory

tx_code-bit_in

In Link Fault Generate, the tx_code-bit parameter as conveyed to the PMA from the PMA client by the PMA_UNITDATA.request.

tx_code-bit_out

In Link Fault Generate, the tx_code-bit parameter to be passed to the TX process. Note that this is called tx_code-bit by the TX process.

The following variables are required only for the optional EEE capability:

lpi_link_fail

The lpi_link_fail parameter is communicated by the PMA_LPILINKFAIL.request primitive. In the LPI mode, this variable is generated by the Receive process of the PCS to control the transition to a Link Down state. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.

Values: TRUE; local receiver has detected a link failure status when in an LPI state
FALSE; local receiver is functioning normally when in an LPI state

rx_lpi

The rx_lpi parameter is communicated by the PMA_RXLPI.request primitive. This variable is generated by the Receive process of the PCS to indicate the LPI mode. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.

Values: TRUE; local receiver is in the LPI mode
FALSE; local receiver is in the normal operation mode

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24.3.3.3 Functions

SHIFTLEFT (rx_bits)

In Carrier Detect, this function shifts rx_bits left one bit placing rx_bits [8] in rx_bits [9], rx_bits [7] in rx_bits [8] and so on until rx_bits [1] gets rx_bits [0].

24.3.3.4 Timers

stabilize_timer

An implementation-dependent delay timer between 330 µs and 1000 µs, inclusive, to ensure that the link is stable.

24.3.3.5 Counters

num_cycles

In Link Fault Detect, a counter containing the number of consecutive Far-End Fault cycles currently sensed. This counter gets reset on initialization or when the bit stream fails to qualify as a potential Far-End Fault Indication. It never exceeds FEF_CYCLES.

num_ones

This represents two separate and independent counters: In Link Fault Generate, a counter containing the number of consecutive ONEs already sent during this cycle of the Far-End Fault Indication. In Link Fault Detect, a counter containing the number of consecutive ONEs currently sensed; it gets reset whenever a ZERO is detected or when the bit stream fails to qualify as a potential Far-End Fault Indication. These counters never exceed FEF_ONES.

24.3.3.6 Messages

PMD_UNITDATA.indicate (rx_nrzi-bit)

A signal sent by the PMD signifying that the next nrzi-bit is available from the medium. nrzi-bit is converted (instantaneously) to code-bit by the RX process and used by the Carrier Detect process.

5xPMD_UNITDATA.indicates

In Carrier Detect, this shorthand notation represents repetition of the preceding state five times synchronized with five successive PMD_UNITDATA.indicates.

PMA_UNITDATA.request (tx_code-bit)

A signal sent by the PMA's client signifying that the next nrzi-bit is available for transmission. For this process, the tx_code-bit parameter is interpreted as tx_code-bit_in.

24.3.4 Process specifications and state diagrams

24.3.4.1 TX

The TX process passes data from the PMA's client directly to the PMD. The PMA shall implement the TX process as follows: Upon receipt of a PMA_UNITDATA.request (tx_code-bit), the PMA performs a conversion to NRZI format and generates a PMD_UNITDATA.request (tx_nrzi-bit) primitive with the same logical value for the tx_nrzi-bit parameter. Note that tx_code-bit is equivalent to tx_code-bit_out of the Link Fault Generate process when implemented.

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24.3.4.2 RX

The RX process passes data from the PMD directly to the PMA's client and to the Carrier Detect process. The PMA shall implement the RX process as follows: Upon receipt of a PMD_UNITDATA.indicate (rx_nrzi-bit), the PMA performs a conversion from NRZI format and generates a PMA_UNITDATA.indicate (rx_code-bit) primitive with the same logical value for the rx_code-bit parameter.

24.3.4.3 Carrier detect

The PMA Carrier Detect process provides repeater clients an indication that a carrier event has been sensed and an indication if it is deemed in error. A carrier event is defined as receipt of two non-contiguous ZEROS within any 10 rx_code-bits. A carrier event is in error if it does not start with an SSD. The Carrier Detect process performs this function by continuously monitoring the code-bits being delivered by the RX process, and checks for specific patterns that indicate non-IDLE activity and SSD bit patterns.

The Carrier Detect process collects code-bits from the PMD RX process. r_bits [9:0] represents a sliding, 10-bit window on the code-bit sequence, with newly received code-bits from the RX process being shifted into r_bits [0]. The process shifts the r_bits vector to the left, inserts the newly received code-bit into position 0, and waits for the next PMD.UNITDATA.indicate before repeating the operation. This is depicted in Figure 24–13. The Carrier Detect process monitors the r_bits vector until it detects two noncontiguous ZEROS in the incoming code-bit sequence. This signals a transition of carrier_status from OFF to ON. Each new carrier is further examined for a leading SSD (1100010001) with rxerror_status set to ERROR if it is not confirmed. A pattern of 10 contiguous ONEs in the stream indicates a return to carrier_status = OFF. Code-bit patterns of contiguous ONEs correspond to IDLE code-groups in the PCS, per the encoding specified in 24.2.2.1.

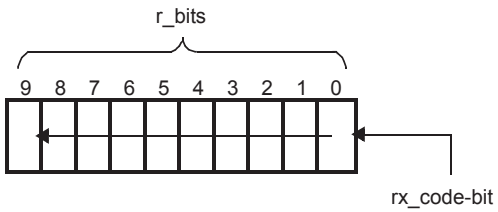

Figure 24–13—Carrier Detect reference diagram

The PMA shall, if it is supporting a repeater, implement the Carrier Detect process as depicted in Figure 24–14 including compliance with the associated state variables as specified in 24.3.3.

24.3.4.4 Link Monitor

The Link Monitor process is responsible for determining whether the underlying receive channel is providing reliable data. Failure of the underlying channel typically causes the PMA's client to suspend normal actions. The Link Monitor process takes advantage of the PMD sublayer's continuously signaled transmission scheme, which provides the PMA with a continuous indication of signal detection on the channel through signal_status as communicated by the PMD_SIGNAL.indicate primitive. It responds to control by Auto-Negotiation, when implemented, which is effected through the link_control parameter of PMA_SIGNAL.request.

The Link Monitor process monitors signal_status, setting link_status to FAIL whenever signal_status is OFF during the normal operation or when Auto-Negotiation sets link_control to DISABLE. If the EEE capability is supported, when the receiver is in the LPI mode, the assertion of lpi_link_fail shall set the link_status to FAIL and eventually brings the receiver out of the LPI mode. The link is deemed to be reliably operating

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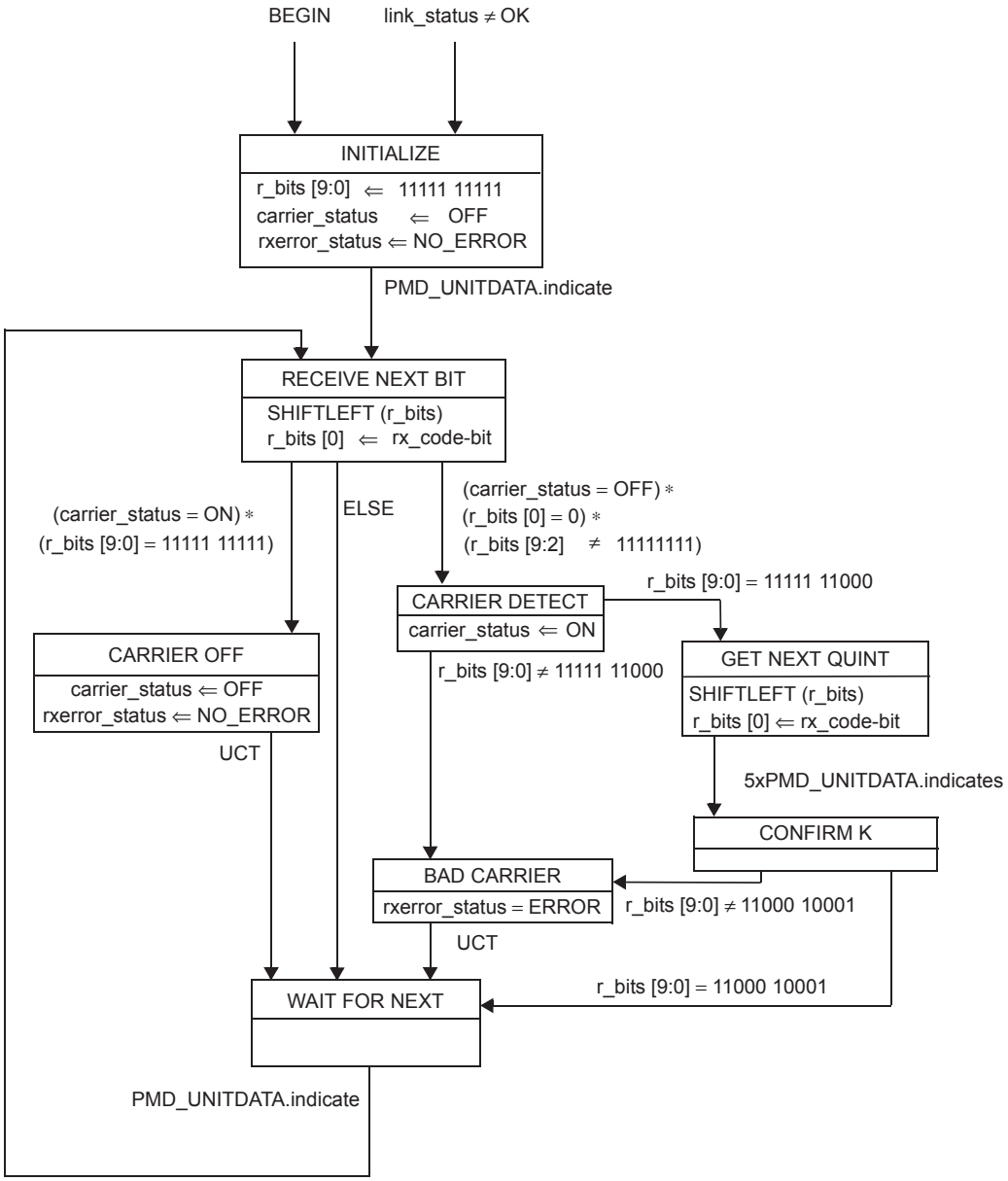

Figure 24–14—Carrier Detect state diagram

when signal_status has been continuously ON for a period of time. This period is implementation dependent but not less than 330 μs or greater than 1000 μs. If so qualified, Link Monitor sets link_status to READY in order to synchronize with Auto-Negotiation, when implemented. Auto-Negotiation permits full operation by setting link_control to ENABLE. When Auto-Negotiation is not implemented, Link Monitor operates with link_control always set to ENABLE.

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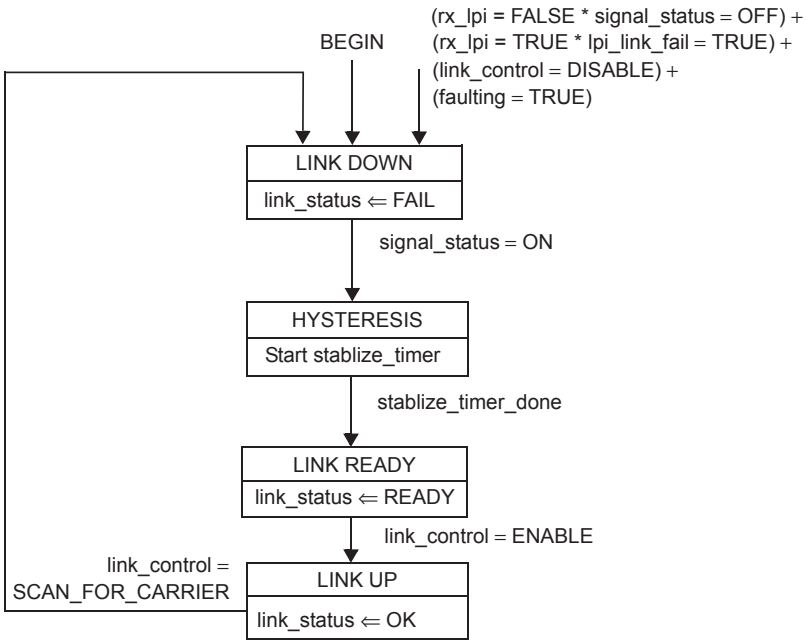
The PMA shall implement the Link Monitor process as depicted in Figure 24–15 including compliance with the associated state variables as specified in 24.3.3.



NOTE 1—The variables link_control and link_status are designated as link_control_[TX] and link_status_[TX], respectively, by the Auto-Negotiation Arbitration state diagram (Figure 28–18).

NOTE 2—The variables rx_lpi and lpi_link_fail are only required for the EEE capability and should be treated as if the value of these two variables is FALSE otherwise.

Figure 24–15—Link Monitor state diagram

24.3.4.5 Far-End Fault Generate

Far-End Fault Generate simply passes tx_code-bits to the TX process when signal_status=ON. When signal_status=OFF and not in the LPI mode, it repetitively generates each cycle of the Far-End Fault Indication until signal_status is reasserted.

If Far-End Fault is implemented, the PMA shall implement the Far-End Fault Generate process as depicted in Figure 24–16 including compliance with the associated state variables as specified in 24.3.3.

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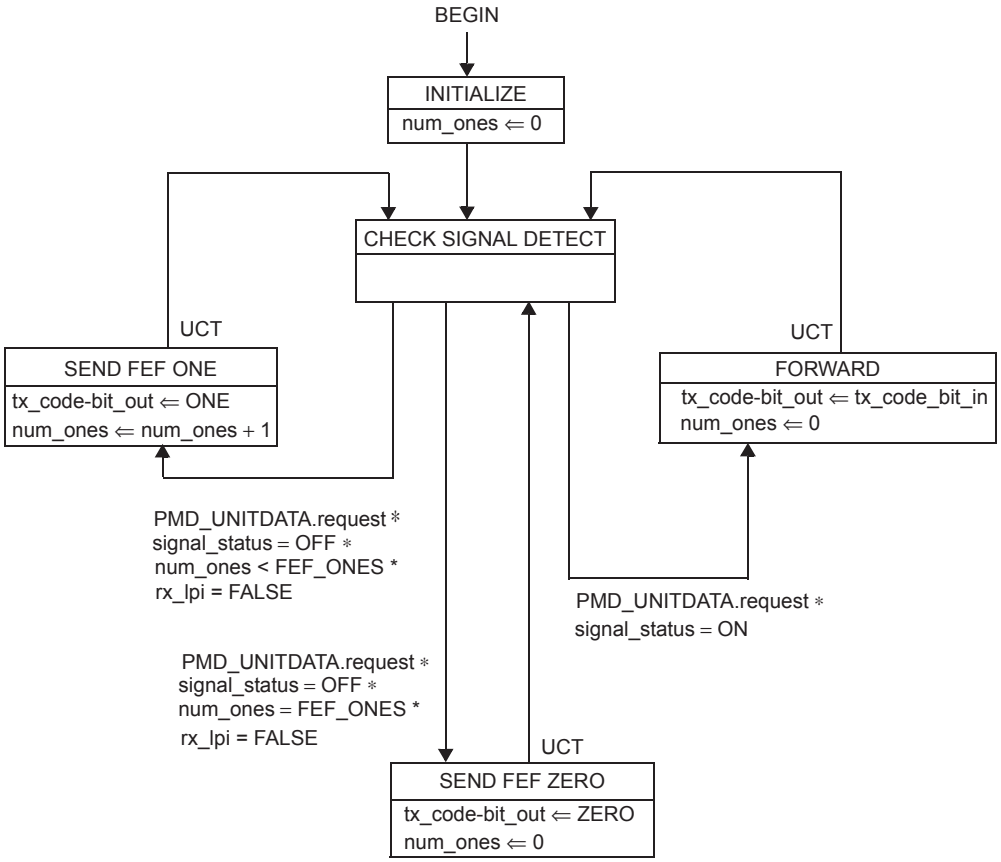

NOTE—The variable rx_lpi is only required for the EEE capability and should be treated as if the value of this variable is FALSE otherwise.

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

24.3.4.6 Far-End Fault Detect

Far-End Fault Detect passively monitors the rx_code-bit stream from the RX process for the Far-End Fault Indication. It does so by maintaining counters for the number of consecutive ONEs seen since the last ZERO (num_ones) and the number of cycles of 84 ONEs and a single ZERO (num_cycles). The Far-End Fault Indication is denoted by three or more cycles, each of 84 ONEs and a single ZERO. Note that the number of consecutive ONEs may exceed 84 on the first cycle.

If Far-End Fault is implemented, the PMA shall implement the Far-End Fault Detect process as depicted in Figure 24–17 including compliance with the associated state variables as specified in 24.3.3.

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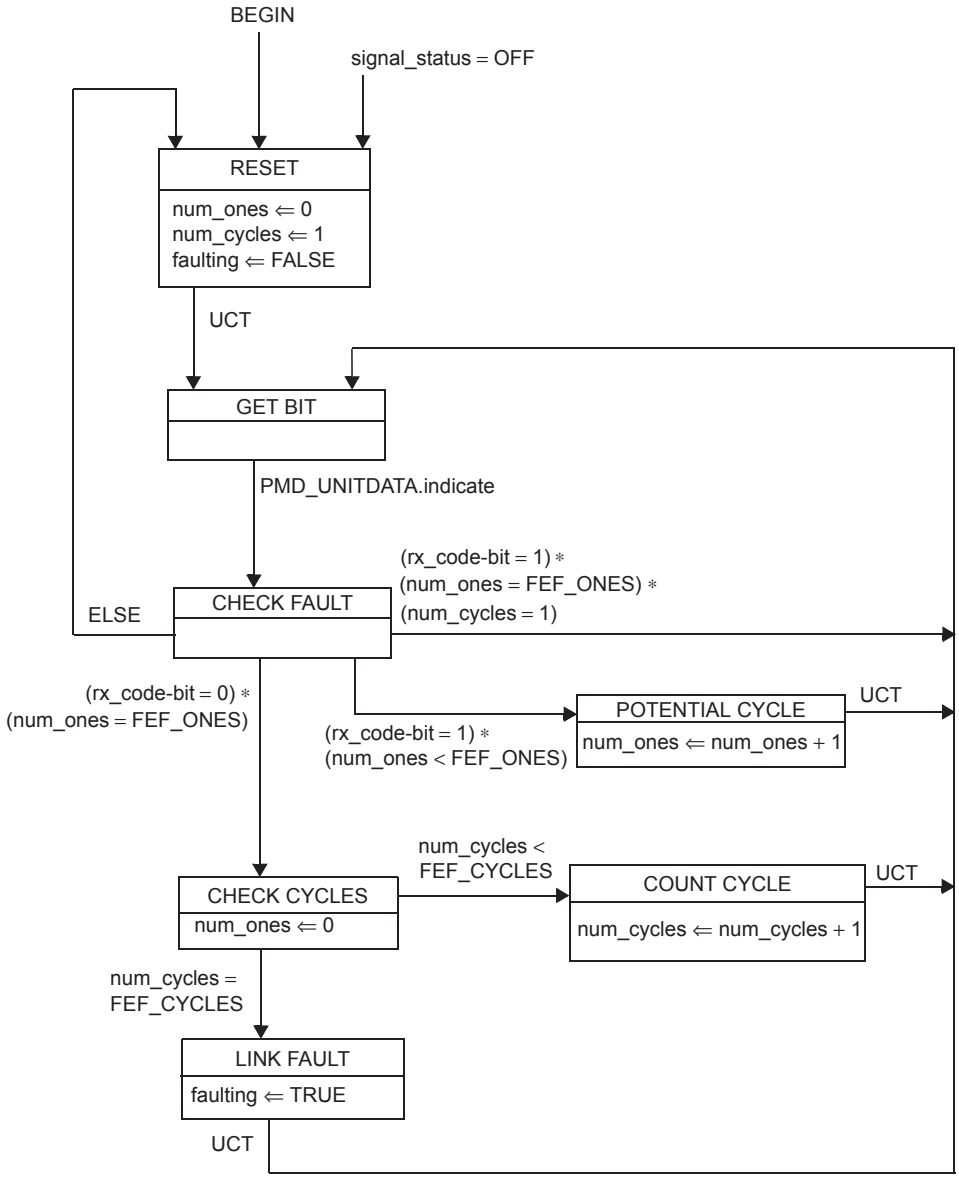

Figure 24–17—Far-End Fault Detect state diagram

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24.4 Physical Medium Dependent (PMD) sublayer service interface

24.4.1 PMD service interface

The following specifies the services provided by the PMD. The PMD is a sublayer within 100BASE-X and may not be present in other 100BASE-T PHY specifications. PMD services are described in an abstract manner and do not imply any particular implementation. It should be noted that these services are functionally identical to those defined in the FDDI standards, such as ISO/IEC 9314-3:1990 and ANSI X3.263-1995, with the following three exceptions:

a) 100BASE-X does not include a Station Management (SMT) function; therefore the PMD-to-SMT interface defined in ISO/IEC 9314-3:1990 and ANSI X3.263-1995.
b) 100BASE-X does not support multiple instances of a PMD in service to a single PMA; therefore, no qualifiers are needed to identify the unique PMD being referenced.
c) 100BASE-X may support LPI for the EEE capability.

There are also *editorial* differences between the interfaces specified here and in the referenced standards, as required by the context of 100BASE-X.

The PMD Service Interface supports the exchange of nrzi-bits between PMA entities. The PMD translates the nrzi-bits to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request
PMD_UNITDATA.indicate
PMD_SIGNAL.indicate
PMD_RXQUIET.request
PMD_TXQUIET.request

24.4.1.1 PMD_UNITDATA.request

This primitive defines the transfer of data (in the form of nrzi-bits) from the PMA to the PMD.

24.4.1.1.1 Semantics of the service primitive

PMD_UNITDATA.request (tx_nrzi-bit)

The data conveyed by PMD_UNITDATA.request is a continuous sequence of nrzi-bits. The tx_nrzi-bit parameter can take one of two values: ONE or ZERO.

24.4.1.1.2 When generated

The PMA continuously sends, at a nominal 125 Mb/s rate, the PMD the appropriate nrzi-bits for transmission on the medium.

24.4.1.1.3 Effect of receipt

Upon receipt of this primitive, the PMD converts the specified nrzi-bit into the appropriate signals on the MDI.

24.4.1.2 PMD_UNITDATA.indicate

This primitive defines the transfer of data (in the form of nrzi-bits) from the PMD to the PMA.

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24.4.1.2.1 Semantics of the service primitive

PMD_UNITDATA.indicate (rx_nrzi-bit)

The data conveyed by PMD_UNITDATA.indicate is a continuous nrzi-bit sequence. The rx_nrzi-bit parameter can take one of two values: ONE or ZERO.

24.4.1.2.2 When generated

The PMD continuously sends nrzi-bits to the PMA corresponding to the signals received from the MDI.

24.4.1.2.3 Effect of receipt

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

24.4.1.3 PMD_SIGNAL.indicate

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

24.4.1.3.1 Semantics of the service primitive

PMD_SIGNAL.indicate (signal_status)

The signal_status parameter can take on one of two values: ON or OFF, indicating whether the quality and level of the received signal is satisfactory (ON) or unsatisfactory (OFF). When signal_status = OFF, then rx_nrzi-bit is undefined, but consequent actions based on PMD_SIGNAL.indicate, where necessary, interpret rx_nrzi-bit as logic ZERO.

24.4.1.3.2 When generated

The PMD generates this primitive to indicate a change in the value of signal_status.

24.4.1.3.3 Effect of receipt

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

24.4.1.4 PMD_RXQUIET.request

This primitive is generated by the Receive Process of the PCS only if EEE is supported to indicate that the receiver is in the LPI mode and the line is in the Quiet state (see 24.2.4.3 and Figure 24–12).

24.4.1.4.1 Semantics of the service primitive

PMD_RXQUIET.request(rx_quiet)

The rx_quiet parameter takes on one of two values, TRUE or FALSE, indicating whether the receiver is in the Quiet state (TRUE) or not (FALSE).

24.4.1.4.2 When generated

The PCS generates this primitive to indicate a Quiet state of the transmitter in the LPI mode.

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24.4.1.4.3 Effect of receipt

This primitive affects operation of the PMD function of type 100BASE-TX as described in 25.5.2. Other use of receipt of this primitive by the client is unspecified by the PMD sublayer.

24.4.1.5 PMD_TXQUIET.request

This primitive is generated by the Transmit Process of the PCS only if EEE is supported to indicate that the transmitter is in the LPI mode and the line is in the Quiet state (see 24.2.4.2 and Figure 24–8).

24.4.1.5.1 Semantics of the service primitive

PMD_TXQUIETrequest(tx_quiet)

The tx_quiet parameter takes on one of two values, TRUE or FALSE, indicating whether the transmitter is in the Quiet state (TRUE) or not (FALSE).

24.4.1.5.2 When generated

The PCS generates this primitive to indicate a Quiet state of the transmitter in the LPI mode.

24.4.1.5.3 Effect of receipt

This primitive affects operation of the PMD function of type 100BASE-TX as described in 25.5.1. Other use of receipt of this primitive by the client is unspecified by the PMD sublayer.

24.4.2 Medium Dependent Interface (MDI)

The MDI, a physical interface associated with a PMD, is comprised of an electrical or optical medium connector. The 100BASE-X MDIs, defined in subsequent clauses, are specified by reference to the appropriate FDDI PMD, such as in ISO/IEC 9314-3:1990 and ANSI X3.263-1995, together with minor modifications (such as connectors and pin-outs) necessary for 100BASE-X.

24.5 Compatibility considerations

There is no requirement for a compliant device to implement or expose any of the interfaces specified for the PCS, PMA, or PMD. However, if an exposed interface is provided to the PCS, it shall comply with the requirements for the MII, as specified in Clause 22.

24.6 Delay constraints

In half duplex mode, proper operation of a CSMA/CD LAN demands that there be an upper bound on the propagation delays through the network. This implies that MAC, PHY, and repeater implementers must conform to certain delay minima and maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

In full duplex mode, predictable operation of the (optional) MAC Control PAUSE operation (Clause 31, Annex 31B) also demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

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MAC constraints are contained in Clause 21. Topological constraints are contained in Clause 29. MAC Control sublayer constraints are contained in Clause 31.

The reference point for all MDI measurements is the 50% point of the mid-cell transition corresponding to the reference code-bit, as measured at the MDI. Although 100BASE-TX output is scrambled, it is assumed that these measurements are made via apparatuses that appropriately account for this.

24.6.1 PHY delay constraints (exposed MII)

Every 100BASE-X PHY with an exposed MII shall comply with the bit delay constraints specified in Table 24–2 and Table 24–3. These figures apply for all 100BASE-X PMDs.

Table 24–2—Bit delay constraints

a) MDI to MII delay constraints (exposed MII, half duplex mode)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MII ⇔ MDI	TX_EN sampled to MDI output	6	14	TX_CLK rising	1st bit of /J/
	MDI input to CRS assert		20	1st bit of /J/	
	MDI input to CRS deassert (aligned)	13	24	1st bit of /T/	
	MDI input to CRS deassert (unaligned)	13	24	1st ONE	
	MDI input to COL assert		20	1st bit of /J/	
	MDI input to COL deassert (aligned)	13	24	1st bit of /T/	
	MDI input to COL deassert (unaligned)	13	24	1st ONE	
	TX_EN sampled to CRS assert	0	4	TX_CLK rising	
	TX_EN sampled to CRS deassert	0	16	TX_CLK rising	

Table 24–3—Bit delay constraints *(continued)*

b) PHY delay constraints (exposed MII, full duplex mode)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MII ⇔ MDI	TX_EN sampled to MDI output		14	TX_CLK rising	1st bit of /J/
	MDI Input to RX_DV deassert		32	first bit of /T/	RX_CLK rising

24.6.2 DTE delay constraints (unexposed MII)

Every 100BASE-X DTE with no exposed MII shall comply with the bit delay constraints specified in Table 24–4. These figures apply for all 100BASE-X PMDs.

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Table 24–4—DTE delay constraints (unexposed MII, half duplex mode)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MAC ⇔ MDI	MAC transmit start to MDI output		18		1st bit of /J/
	MDI input to MDI output (worst-case nondeferred transmit)		54	1st bit of /J/	1st bit of /J/
	MDI input to collision detect		28	1st bit of /J/	
	MDI input to MDI output = Jam (worst case collision response)		54	1st bit of /J/	1st bit of jam

24.6.3 Carrier deassertion/assertion constraint (half duplex mode only)

To ensure fair access to the network, each DTE shall, additionally, satisfy the following:

(MAX MDI to MAC Carrier Deassert Detect) – (MIN MDI to MAC Carrier Assert Detect) < 13

24.7 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801.

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24.8 Protocol implementation conformance statement (PICS) proforma for Clause 24, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X[6]

24.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 24, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X, 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.

24.8.2 Identification

24.8.2.1 Implementation identification

Supplier	
Contact point for inquiries 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)	
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).	

24.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-201x, Clause 24, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X
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 802.3-201x.)	

Date of Statement	

[6]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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24.8.2.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*DTE	Supports DTE without MII	24.4	O/1		
*REP	Supports Repeater without MII	24.4	O/1		
*MII	Supports exposed MII interface	24.4	O/1		
*PCS	Implements PCS functions	24.2	REP: O DTE: M MII: M		
PMA	Implements PMA RX, TX and Link Monitor functions	24.3	M		
*LPC	PCS implementation of LPI	24.2	PCS:O		
*LPM	PMA implementation of LPI	24.3	LPC:M		
*NWC	Medium capable of supporting Auto-Negotiation		O		See Clause 28
*FEF	Implements Far-End Fault	24.3.2.1	NWC: X LPM:X		
NWY	Supports Auto-Negotiation (Clause 28)	24.1.4.4	NWC: O LPC:M		See Clause 28

24.8.3 PICS proforma tables for the Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X

24.8.3.1 General compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
GN1	Compliance with MII requirements	24.4	MII:M		See Clause 22
GN2	Environmental specifications	24.7	M		

24.8.3.2 PCS functions

Item	Feature	Subclause	Status	Support	Value/Comment
PS1	Transmit Bits process	24.2.4.1	PCS:M		
PS2	Transmit process	24.2.4.2	PCS:M		
PS3	Receive Bits process	24.2.4.3	PCS:M		
PS4	Receive process	24.2.4.4	PCS:M		
PS5	Carrier Sense process	24.2.4.5	PCS:M		

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24.8.3.3 PMA functions

Item	Feature	Subclause	Status	Support	Value/Comment
PA1	TX process	24.3.4.1	M		
PA2	RX process	24.3.4.2	M		
PA3	Carrier Detect process	24.3.2.1	REP: M		
PA4	Link Monitor process	24.3.4.4	M		
PA5	Far-End Fault Generate process	24.3.4.5	FEF: M		
PA6	Far-End Fault Detect process	24.3.4.6	FEF: M		

24.8.3.4 Timing

Item	Feature	Subclause	Status	Support	Value/Comment
TM1	Support for MII signals TX_CLK and RX_CLK	24.2.2.3	MII:M		See Clause 22
TM2	Accuracy of code-bit_timer	24.2.3	M		
TM3	Compliance with PHY bit delay constraints	24.6.1	MII:M REP: O		
TM4	Compliance with DTE bit delay constraints	24.6.2	DTE:M		
TM5	Compliance with Carrier Deassert/Assert Constraint	24.6.3	DTE:M		

24.8.3.5 LPI functions

Item	Feature	Subclause	Status	Support	Value/Comment
LF1	lpi_rx_ti_timer	24.2.3.4	LPC:M		The timer has a period between 0.8–0.9 μs.
LF2	lpi_rx_tq_timer	24.2.3.4	LPC:M		The timer has a period between 24–26 ms.
LF3	lpi_rx_ts_timer	24.2.3.4	LPC:M		The timer has a period between 240–260 μs.
LF4	lpi_rx_tw_timer	24.2.3.4	LPC:M		The timer has a period that does not exceed 20.5 μs.
LF5	LPI wake error counter	24.2.3.4	LPC:M		Increment the wake error counter for each transition of lpi_rx_tw_timer_done from false to true.

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Item	Feature	Subclause	Status	Support	Value/Comment
LF6	lpi_tx_tq_timer	24.2.3.4	LPC:M		The timer has a period between 20–22 ms.
LF7	link failure caused by lpi_rx-_tq_timer	24.2.3.4	LPC:M		The receiver assumes a link failure if the PHY fails to receive a valid Refresh or Wake signal before the lpi_rx_tq_timer expires.
LF8	lpi_tx_ts_timer	24.2.3.4	LPC:M		The timer has a period between 200–220 µs.
LF9	lpi_link_fail_timer	24.2.3.4	LPC:M		The timer has a period between 90–110 µs.
LF11	lpi_link_fail	24.3.3.2	LPM:M		The PHY operates as if the value of this variable is FALSE in the absence of the optional EEE capability.
LF12	rx_lpi	24.3.3.2	LPM:M		The PHY operates as if the value of this variable is FALSE in the absence of the optional EEE capability.
LF13	link_status affected by lpi_link_fail	24.3.4.4	LPM:M		The assertion of lpi_link_fail sets the link_status to FAIL if the EEE is supported and the receiver is in the LPI mode.

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