Non line-code elements for the 10GBASE-T standard

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Proposal

- **10GBASE-T framework for non line code dependent functions be adapted directly from 1000BASE-T.**
- **Backup material follows**
  - **1000BASE-T has been changed to 10GBASE-T**
  - **GMII has been changed to XGMII**
  - **Some text relating to half-duplex removed**
  - **TBD indicates text relative to FEC and line coding**
- **Proposal: Give this data to the editor with the directive to adapt as much directly from 1000BASE-T as possible.**

55.1 Overview

The 10GBASE-T PHY is one of the 10 Gigabit Ethernet family of high-speed network specifications. The 10GBASE-T Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) and baseband medium specifications are intended for users who want 10 Gb/s performance over TBD balanced twisted-pair cabling systems. 10GBASE-T signaling requires four pairs of TBD balanced cabling, as specified in ISO/IEC TBD and ANSI/TIA TBD.

This clause defines the type 10GBASE-T PCS, type 10GBASE-T PMA sublayer, and type 10GBASE-T Medium Dependent Interface (MDI). Together, the PCS and the PMA sublayer comprise a 10GBASE-T Physical layer (PHY). Provided in this document are fully functional, electrical, and mechanical specifications for the type 10GBASE-T PCS, PMA, and MDI. This clause also specifies the baseband medium used with 10GBASE-T.

55.1.1 Objectives

The following are the objectives of 10GBASE-T:

a) Support the full duplex Ethernet MAC

b) Comply with the specifications for the XGMII (Clause 46)

c) Meet or exceed FCC Class A/CISPR or better operation

d) Support operation over 100 meters of Category 6 balanced cabling as defined in (TBD)

e) Support Auto-Negotiation (Clause 28)

f) Support a BER objective of 10E–12

55.1.2 Relationship of 10GBASE-T to other standards

Relations between the 10GBASE-T PHY, the ISO Open Systems Interconnection (OSI) Reference Model, and the IEEE 802.3 CSMA/CD LAN Model are shown in Figure (TBD). The PHY sub-layers (shown shaded) in Figure (TBD) connect one Clause 4 Media Access Control (MAC) layer to the medium.

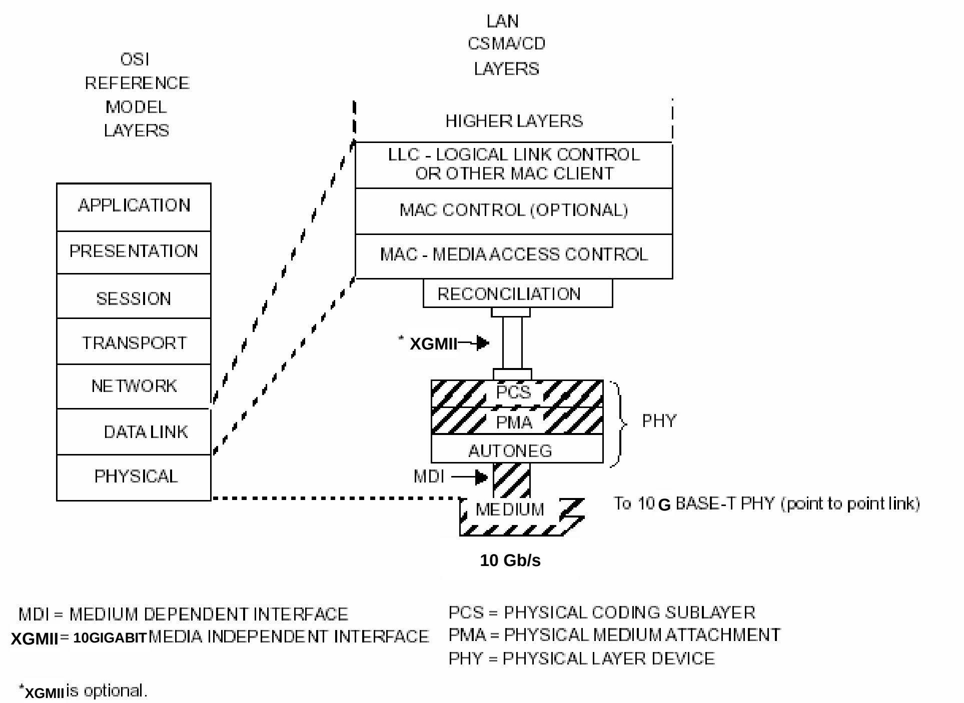


Figure ? –1—Type 10 G BASE-T PHY relationship to the ISO Open Systems Interconnection (OSI) Reference Model and the IEEE 802.3 CSMA/CD LAN Model

55.1.3 Operation of 10GBASE-T

The 10GBASE-T PHY employs full duplex baseband transmission over four pairs of augmented Category 6 balanced cabling. The aggregate data rate of 10 Gb/s is achieved by transmission at a data rate of 2.5 Gb/s over each wire pair, as shown in Figure TBD–2. The use of hybrids and cancellers enables full duplex transmission by allowing symbols to be transmitted and received on the same wire pairs at the same time. **TBD** signaling with a modulation rate of **TBD** Mbaud is used on each of the wire pairs. The transmitted symbols are selected from a **TBD** symbol constellation. Each **TBD** symbol can be viewed as **TBD.** 10GBASE-T uses a continuous signaling system; in the absence of data, Idle symbols are transmitted. Idle mode is **TBD**. **TBD** modulation is employed for transmission over each wire pair. The modulation rate of **TBD** MBaud results in a symbol period of **TBD** ns.

A 10GBASE-T PHY can be configured either as a MASTER PHY or as a SLAVE PHY. The MASTER-SLAVE relationship between two stations sharing a link segment is established during Auto-Negotiation (see Clause 28, 40.5, and Annex 28C). The MASTER PHY uses a local clock to determine the timing of transmitter operations. The SLAVE PHY recovers the clock from the received signal and uses it to determine the timing of transmitter operations, i.e., it performs loop timing, as illustrated in Figure TBD-3. In a multiport to single-port connection, the multiport device is typically set to be MASTER and the single-port device is set to be SLAVE.

The PCS and PMA subclauses of this document are summarized in **TBD** and **TBD**. Figure **TBD**–3 shows the functional block diagram.

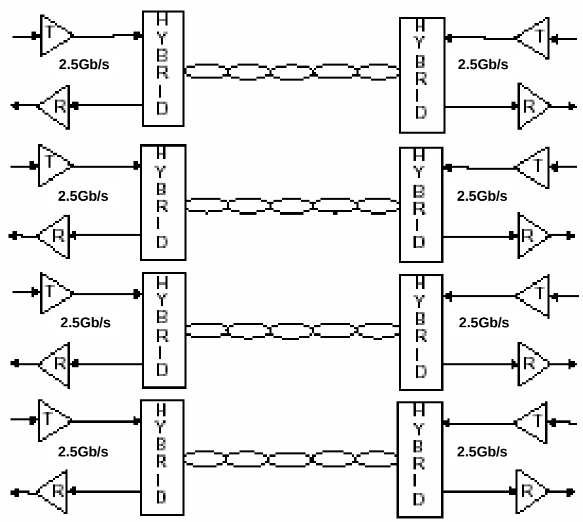
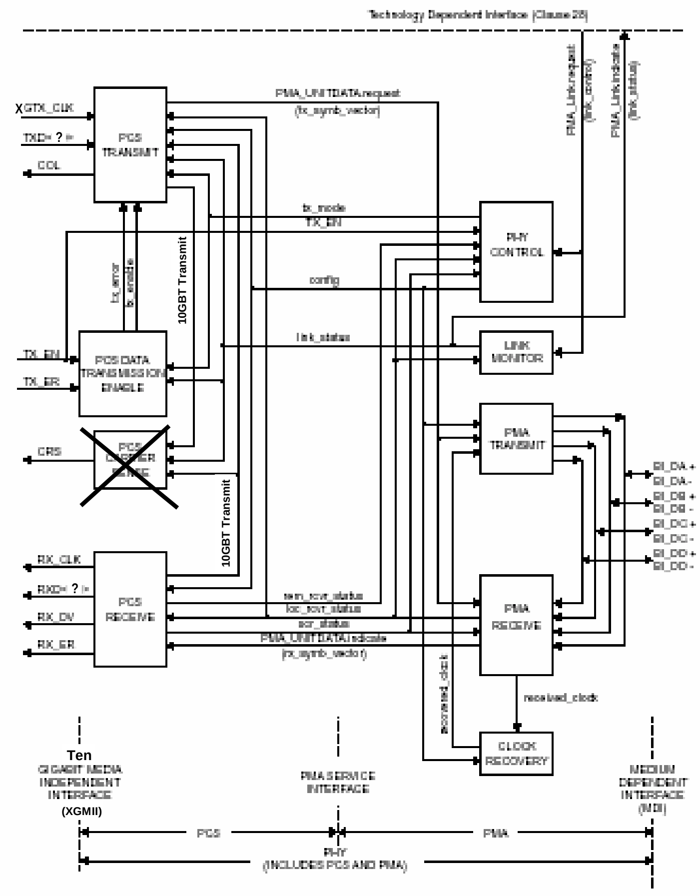


Figure ? -2— 10 G BASE-T topology



NOTE The recovered_clock arc is shown to indicate delivery of the received clock signal back to PMA TRANSMIT for loop timing.

Figure ? -3— Functional block diagram

55.1.3.1 Physical Coding Sublayer (PCS)

The 10GBASE-T PCS couples a Ten Gigabit Media Independent Interface (XGMII), as described in Clause 46, to a Physical Medium Attachment (PMA) sublayer.

The functions performed by the PCS comprise the generation of continuous code-groups to be transmitted over four channels and the processing of code-groups received from the remote PHY. The process of converting data bits to code-groups is called **TBD**, which refers to the coding technique used. Through this coding scheme, **TBD** bits are converted to **TBD** transmission of **TBD** symbols.

During the beginning of a frame's transmission, when a Start control character appears on lane 0 of the XGMII, a Start-of-Stream delimiter is transmitted followed by code-groups representing the **TBD** coming from the XGMII. Immediately following the data **TBD**, the XGMII sends a Terminate control character, upon which the end of a frame is transmitted. The end of a frame consists of an End-of-Stream delimiter symbol. The end of a frame is followed by a series of symbols encoded in the idle mode

Between frames, **TBD** is transmitted. This is called idle mode. Idle mode encoding takes into account the information of whether the local PHY is operating reliably or not and allows this information to be conveyed to the remote station. During normal operation, idle mode is followed by a data mode that begins with a Start-of-Stream delimiter.

55.1.3.1 Physical Coding Sublayer (PCS) Continued

Further patterns are used for signaling a transmit error and other control functions during transmission of a data stream.

The PCS Receive processes code-groups provided by the PMA. The PCS Receive detects the beginning and the end of frames of data and, during the reception of data, descrambles and decodes the received code groups into a group of four **TBD** RXD<31:0> that are passed to the XGMII. The conversion of code-groups to **TBD** uses a **TBD** data decoding technique. PCS Receive also detects errors in the received sequences and signals them to the XGMII. Furthermore, the PCS contains a management interface.

The signals provided by the PCS at the XGMII conform to the interface requirements of Clause 46. The PCS Service Interfaces to the XGMII and the PMA are abstract message-passing interfaces.

55.1.3.2 Physical Medium Attachment (PMA) sublayer

The PMA couples messages from the PMA service interface onto the balanced cabling physical medium and provides the link management and PHY Control functions. The PMA provides full duplex communications at **TBD** MBaud over four pairs of balanced cabling up to 100 m in length.

The PMA Transmit function comprises four independent transmitters to generate **TBD** modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD, as described in **TBD**.

The PMA Receive function comprises four independent receivers for **TBD** modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD, as described in **TBD**. This signal encoding technique is referred to as **TBD**. The receivers are responsible for acquiring clock and providing code-groups to the PCS as defined by the PMA_UNITDATA.indicate message. The PMA also contains functions for Link Monitor.

The PMA PHY Control function generates signals that control the PCS and PMA sublayer operations. PHY Control begins following the completion of Auto-Negotiation and provides the start-up functions required for successful **TBD** operation. It determines whether the PHY operates in a normal state, enabling data transmission over the link segment, or whether the PHY sends special code-groups that represent the idle mode. The latter occurs when either one or both of the PHYs that share a link segment are not operating reliably.

PMA functions and state diagrams are specified in **TBD**. PMA electrical specifications are given in **TBD**.

55.1.4 Signaling

10GBASE-T signaling is performed by the PCS generating continuous code-group sequences that the PMA transmits over each wire pair. The signaling scheme achieves a number of objectives including

a) Forward Error Correction (FEC) coded symbol mapping for data.

b) Algorithmic mapping and inverse mapping from **TBD** data to **TBD** symbols and back.

c) Uncorrelated symbols in the transmitted symbol stream.

d) No correlation between symbol streams traveling both directions on any pair combination.

e) No correlation between symbol streams on pairs BI_DA, BI_DB, BI_DC, and BI_DD.

f) Idle mode uses a subset of code-groups in that each symbol is restricted to the set **TBD** to ease synchronization, start-up, and retraining.

g) Ability to rapidly or immediately determine if a symbol stream represents data or idle or carrier extension.

h) Robust delimiters for Start-of-Stream delimiter (SSD), End-of-Stream delimiter (ESD), and other control signals.

55.1.4 Signaling Continued

i) Ability to signal the status of the local receiver to the remote PHY to indicate that the local receiver is not operating reliably and requires retraining.

j) Ability to automatically detect and correct for pair swapping and unexpected crossover connections.

k) Ability to automatically detect and correct for incorrect polarity in the connections.

l) Ability to automatically correct for differential delay variations across the wire-pairs.

The PHY operates in two basic modes, normal mode or training mode. In normal mode, PCS generates code-groups that represent data, control, or idles for transmission by the PMA. In training mode, the PCS is directed to generate only idle code-groups for transmission by the PMA, which enable the receiver at the other end to train until it is ready to operate in normal mode. (See the PCS reference diagram in **TBD**.)

55.1.5 Inter-sublayer interfaces

All implementations of the balanced cabling link are compatible at the MDI. Designers are free to implement circuitry within the PCS and PMA in an application-dependent manner provided that the MDI and XGMII (if the XGMII is implemented) specifications are met. When the PHY is incorporated within the physical bounds of a single-port device or a multiport device, implementation of the XGMII is optional. System operation from the perspective of signals at the MDI and management objects are identical whether the XGMII is implemented or not.

55.1.6 Conventions in this clause

The body of this clause contains state diagrams, including 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.

The values of all components in test circuits shall be accurate to within within $\pm 1\%$ unless otherwise stated.

Default initializations, unless specifically specified, are left to the implementor.

55.2 10GBASE-T Service Primitives and Interfaces

10GBASE-T transfers data and control information across the following four service interfaces:

a) Ten Gigabit Media Independent Interface (XGMII)

b) PMA Service Interface

c) Medium Dependent Interface (MDI)

d) Technology-Dependent Interface

The XGMII is specified in Clause 35; the Technology-Dependent Interface is specified in Clause 28. The

PMA Service Interface is de.ned in 40.2.2 and the MDI is de.ned in 40.8.

55.2.1 Technology-Dependent Interface

10GBASE-T uses the following service primitives to exchange status indications and control signals across the Technology-Dependent Interface as specified in Clause 28:

PMA_LINK.request (link_control)

PMA_LINK.indicate (link_status)

55.2.1.1 PMA_LINK.request

This primitive allows the Auto-Negotiation algorithm to enable and disable operation of the PMA as specified in 28.2.6.2.

55.2.1.1.1 Semantics of the primitive

PMA_LINK.request (link_control)

The link_control parameter can take on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

SCAN_FOR_CARRIER Used by the Auto-Negotiation algorithm prior to receiving any fast link pulses. During this mode the PMA reports link_status=FAIL.PHY processes are disabled.

DISABLE Set by the Auto-Negotiation algorithm in the event fast link pulses are detected. PHY processes are disabled. This allows the Auto-Negotiation algorithm to determine how to configure the link.

ENABLE Used by Auto-Negotiation to turn control over to the PHY for data processing functions.

55.2.1.1.2 When generated

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

55.2.1.2 PMA_LINK.indicate

This primitive is generated by the PMA to indicate the status of the underlying medium as specified in 28.2.6.1. This primitive informs the PCS, PMA PHY Control function, and the Auto-Negotiation algorithm about the status of the underlying link.

55.2.1.2.1 Semantics of the primitive

PMA_LINK.indicate (link_status)

The link_status parameter can take on one of three values: FAIL, READY, or OK.

FAIL No valid link established.

READY The Link Monitor function indicates that a 10GBASE-T link is intact and ready to be established.

OK The Link Monitor function indicates that a valid 10GBASE-T link is established. Reliable reception of signals transmitted from the remote PHY is possible.

55.2.1.2.2 When generated

The PMA generates this primitive continuously to indicate the value of link_status in compliance with the state diagram given in Figure ?–16.

55.2.1.2.3 Effect of receipt

The effect of receipt of this primitive is specified in **TBD**.

55.2.2 PMA Service Interface

10GBASE-T uses the following service primitives to exchange symbol vectors, status indications, and control signals across the service interfaces:

PMA_TXMODE.indicate (tx_mode)

PMA_CONFIG.indicate (con.g)

PMA_UNITDATA.request (tx_symb_vector)

PMA_UNITDATA.indicate (rx_symb_vector)

PMA_SCRSTATUS.request (scr_status)

PMA_RXSTATUS.indicate (loc_rcvr_status)

PMA_REMRXSTATUS.request (rem_rcvr_status)

The use of these primitives is illustrated in Figure ?–4.

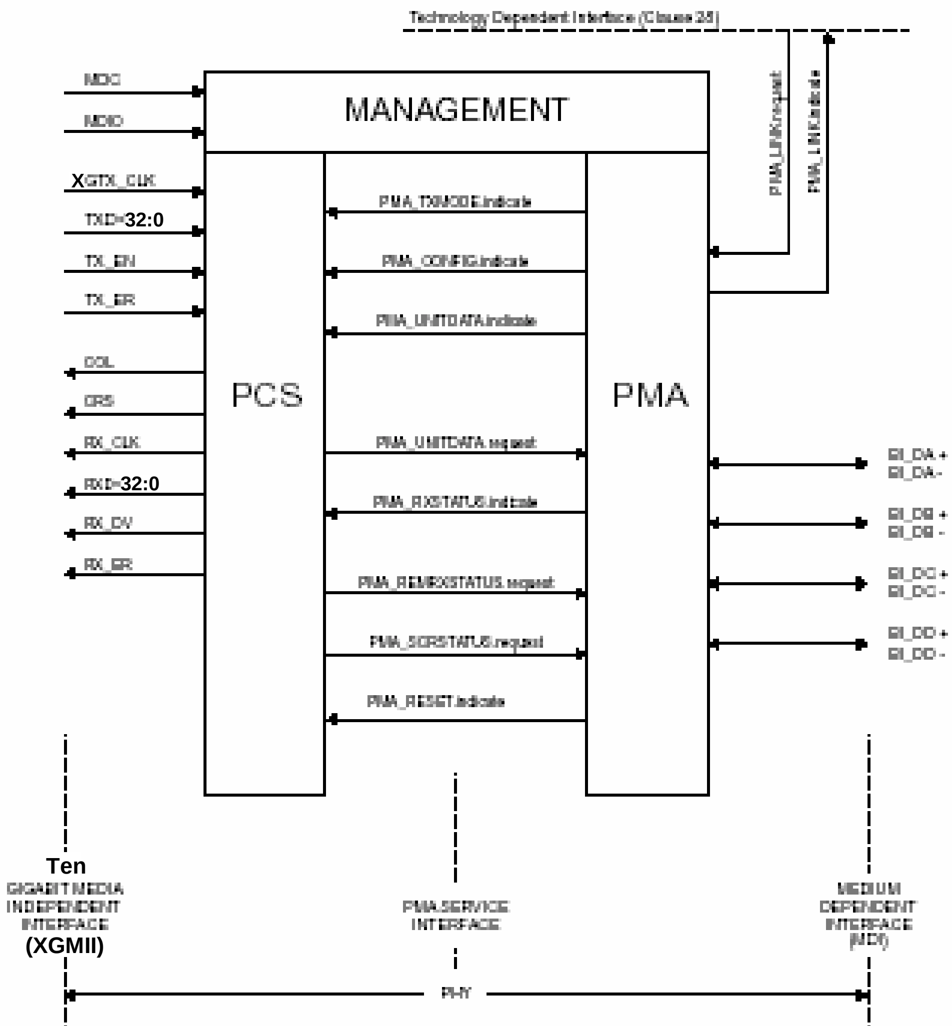


Figure ? -4 — 10GBASE-T service interfaces

55.2.3 PMA_TXMODE.indicate

The transmitter in a 10GBASE-T link normally sends over the four pairs, code-groups that can represent a XGMII data stream, control information, or idles.

55.2.3.1 Semantics of the primitive

PMA_TXMODE.indicate (tx_mode)

PMA_TXMODE.indicate specifies to PCS Transmit via the parameter tx_mode what sequence of codegroups the PCS should be transmitting. The parameter tx_mode can take on one of the following three values of the form:

SEND_N This value is continuously asserted when transmission of sequences of code-
groups representing an XGMII data stream (data mode), control mode or idle
mode is to take place.

SEND_I This value is continuously asserted in case transmission of sequences of code-
groups representing the idle mode is to take place.

SEND_Z This value is continuously asserted in case transmission of zeros is required.

55.2.3.2 When generated

The PMA PHY Control function generates PMA_TXMODE.indicate messages continuously.

55.2.3.3 Effect of receipt

55.2.4 PMA_CONFIG.indicate

Each PHY in a 10GBASE-T link is capable of operating as a MASTER PHY and as a SLAVE PHY. MASTER-SLAVE configuration is determined during Auto-Negotiation (40.5). The result of this negotiation is provided to the PMA.

55.2.4.1 Semantics of the primitive

PMA_CONFIG.indicate (config)

PMA_CONFIG.indicate specifies to PCS and PMA Transmit via the parameter config whether the PHY must operate as a MASTER PHY or as a SLAVE PHY. The parameter config can take on one of the following two values of the form:

MASTER This value is continuously asserted when the PHY must operate as a MASTER PHY.

SLAVE This value is continuously asserted when the PHY must operate as a SLAVE PHY.

55.2.4.2 When generated

PMA generates PMA_CONFIG.indicate messages continuously.

55.2.4.3 Effect of receipt

PCS and PMA Clock Recovery perform their functions in MASTER or SLAVE configuration according to

the value assumed by the parameter config.

55.2.5 PMA_UNITDATA.request

This primitive defines the transfer of code-groups in the form of the tx_symb_vector parameter from the PCS to the PMA. The code-groups are obtained in the PCS Transmit function using the encoding rules defined in TBD to represent XGMII data streams, an idle mode, or other sequences.

55.2.5.1 Semantics of the primitive

PMA_UNITDATA.request (tx_symb_vector)

During transmission, the PMA_UNITDATA.request simultaneously conveys to the PMA via the parameter tx_symb_vector the value of the symbols to be sent over each of the four transmit pairs BI_DA, BI_DB, BI_DC, and BI_DD. The tx_symb_vector parameter takes on the form:

SYMB_4D A vector of four **TBD** symbols, one for each of the four transmit pairs BI_DA,
BI_DB, BI_DC, and BI_DD. Each **TBD** symbol may take on one of the values **TBD**.

The quinary symbols that are elements of tx_symb_vector are called, according to the pair on which each will be transmitted, tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD].

55.2.5.2 When generated

The PCS generates PMA_UNITDATA.request (SYMB_4D) synchronously with every transmit clock cycle.

55.2.5.3 Effect of receipt

Upon receipt of this primitive the PMA transmits on the MDI the signals corresponding to the indicated **TBD** symbols. The parameter tx_symb_vector is also used by the PMA Receive function to process the signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DD.

55.2.6 PMA_UNITDATA.indicate

This primitive defines the transfer of code-groups in the form of the rx_symb_vector parameter from the PMA to the PCS.

55.2.6.1 Semantics of the primitive

PMA_UNITDATA.indicate (rx_symb_vector)

During reception the PMA_UNITDATA.indicate simultaneously conveys to the PCS via the parameter rx_symb_vector the values of the symbols detected on each of the four receive pairs BI_DA, BI_DB, BI_DC, and BI_DD. The rx_symbol_vector parameter takes on the form:

SYMB_4D A vector of four **TBD** symbols, one for each of the four receive pairs BI_DA, BI_DB, BI_DC, and BI_DD. Each **TBD** symbol may take on one of the values **TBD**.

The **TBD** symbols that are elements of rx_symb_vector are called, according to the pair upon which each symbol was received, rx_symbol_vector[BI_DA], rx_symbol_vector[BI_DB], rx_symbol_vector[BI_DC], and rx_symb_vector[BI_DD].

55.2.6.2 When generated

The PMA generates PMA_UNITDATA.indicate (SYMB_4D) messages synchronously with signals received at the MDI. The nominal rate of the PMA_UNITDATA.indicate primitive is **TBD** MHz, as governed by the recovered clock.

55.2.6.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

55.2.7 PMA_SCRSTATUS.request

This primitive is generated by PCS Receive to communicate the status of the descrambler for the local PHY. The parameter scr_status conveys to the PMA Receive function the information that the descrambler has achieved synchronization.

55.2.7.1 Semantics of the primitive

PMA_SCRSTATUS.request (scr_status)

The scr_status parameter can take on one of two values of the form:

OK	The descrambler has achieved synchronization.
NOT_OK	The descrambler is not synchronized.

55.2.7.2 When generated

PCS Receive generates PMA_SCRSTATUS.request messages continuously.

55.2.7.3 Effect of receipt

The effect of receipt of this primitive is specidied in **TBD**.

55.2.8 PMA_RXSTATUS.indicate

This primitive is generated by PMA Receive to indicate the status of the receive link at the local PHY. The parameter loc_rcvr_status conveys to the PCS Transmit, PCS Receive, PMA PHY Control function, and Link Monitor the information on whether the status of the overall receive link is satisfactory or not. Note that loc_rcvr_status is used by the PCS Receive decoding functions. The criterion for setting the parameter loc_rcvr_status is left to the implementor. It can be based, for example, on observing the mean-square error at the decision point of the receiver and detecting errors during reception of symbol streams that represent the idle mode.

55.2.8.1 Semantics of the primitive

PMA_RXSTATUS.indicate (loc_rcvr_status)

The loc_rcvr_status parameter can take on one of two values of the form:

OK This value is asserted and remains true during reliable operation of the receive
link for the local PHY.

NOT_OK This value is asserted whenever operation of the link for the local PHY is unreliable.

55.2.8.2 When generated

PMA Receive generates PMA_RXSTATUS.indicate messages continuously on the basis of signals received at the MDI.

55.2.8.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure ?–15 and in subclauses TBD.

55.2.9 PMA_REMRXSTATUS.request

This primitive is generated by PCS Receive to indicate the status of the receive link at the remote PHY as communicated by the remote PHY via its encoding of its loc_rcvr_status parameter. The parameter rem_rcvr_status conveys to the PMA PHY Control function the information on whether reliable operation of the remote PHY is detected or not. The criterion for setting the parameter rem_rcvr_status is left to the implementor. It can be based, for example, on asserting rem_rcvr_status is NOT_OK until loc_rcvr_status is OK and then asserting the detected value of rem_rcvr_status after proper PCS receive decoding is achieved.

55.2.9.1 Semantics of the primitive

PMA_REMRXSTATUS.request (rem_rcvr_status)

The rem_rcvr_status parameter can take on one of two values of the form:

OK	The receive link for the remote PHY is operating reliably.
NOT_OK	Reliable operation of the receive link for the remote PHY is not detected.

55.2.9.2 When generated

The PCS generates PMA_REMRXSTATUS.request messages continuously on the basis on signals received at the MDI.

55.2.9.3 Effect of receipt

The effect of receipt of this primitive is speci.ed in Figure ?–15.

55.2.10 PMA_RESET.indicate

This primitive is used to pass the PMA Reset function to the PCS (pcs_reset=ON) when reset is enabled.

The PMA_RESET.indicate primitive can take on one of two values:

TRUE	Reset is enabled.
FALSE	Reset is not enabled.

55.2.10.1 When generated

The PMA Reset function is executed as described in TBD.

55.2.10.2 Effect of receipt

The effect of receipt of this primitive is specified in TBD.

55.3 Physical Coding Sublayer (PCS)

The PCS comprises one PCS Reset function and four simultaneous and asynchronous operating functions. The PCS operating functions are: PCS Transmit Enable, PCS Transmit, PCS Receive, and PCS Carrier Sense. All operating functions start immediately after the successful completion of the PCS Reset function.

The PCS reference diagram, Figure ?–5, shows how the four operating functions relate to the messages of the PCS-PMA interface. Connections from the management interface (signals MDC and MDIO) to other layers are pervasive, and are not shown in the figure. Management is specified in Clause 30. See also Figure ?–7, which defines the structure of frames passed from PCS to PMA.

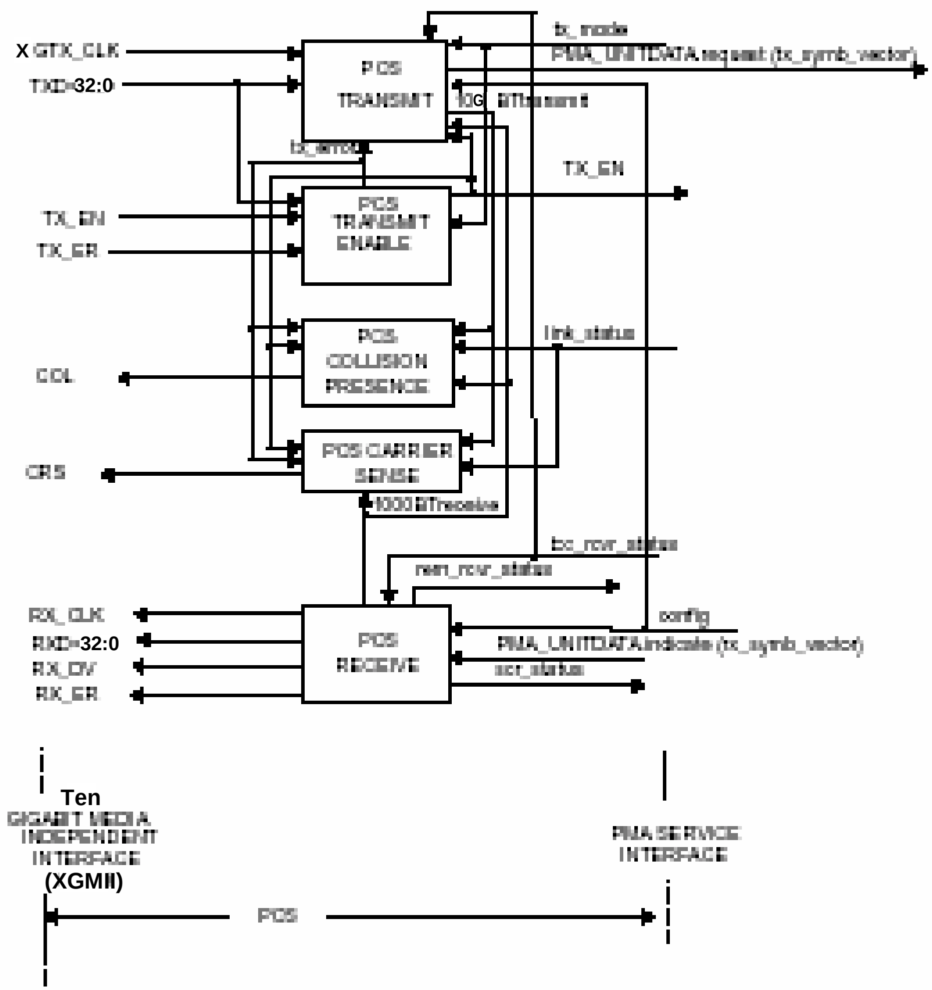


Figure ? -6 – PCS reference diagram

55.3.1 PCS functions

55.3.1.1 PCS Reset function

PCS Reset initializes all PCS functions. The PCS Reset function shall be executed whenever one of the following conditions occur:

a) Power on (see 36.2.5.1.3).

b) The receipt of a request for reset from the management entity.

PCS Reset sets pcs_reset=ON while any of the above reset conditions hold true. All state diagrams take the open-ended pcs_reset branch upon execution of PCS Reset. The reference diagrams do not explicitly show the PCS Reset function.

55.3.1.2 PCS Data Transmission Enable

The PCS Data Transmission Enabling process generates the signals tx_enable and tx_error, which PCS Transmit uses for data and carrier extension encoding. The process uses logical operations on tx_mode, TX_ER, TX_EN, and TXD<7:0>. The PCS shall implement the Data Transmission Enabling process as depicted in Figure ?–8 including compliance with the associated state variables as specified in TBD.

55.3.1.3 PCS Transmit function

The PCS Transmit function shall conform to the PCS Transmit state diagram in Figure ?–9.

In each symbol period, PCS Transmit generates a code-group (An, Bn, Cn, Dn) that is transferred to the PMA via the PMA_UNITDATA.request primitive. The PMA transmits symbols An, Bn, Cn, Dn over wire-pairs BI_DA, BI_DB, BI_DC, and BI_DD respectively. The integer, n, is a time index that is introduced to establish a temporal relationship between different symbol periods. A symbol period, T, is nominally equal to **TBD** ns. In normal mode of operation, between streams of data indicated by the parameter tx_enable, PCS Transmit generates sequences of vectors using the encoding rules defined for the idle mode. Upon assertion of tx_enable, PCS Transmit passes a SSD of two consecutive vectors of four TBD symbols to the PMA, replacing the first two preamble **TBD**. Following the SSD, each TXD<?:0> **TBD** is encoded using an **TBD** technique into a vector of four **TBD** symbols until tx_enable is de-asserted. If TX_ER is asserted while tx_enable is also asserted, then PCS Transmit passes to the PMA vectors indicating a transmit error. Note that if the signal TX_ER is asserted while SSD is being sent, the transmission of the error condition is delayed until transmission of SSD has been completed. Following the de-assertion of tx_enable, a Convolutional State Reset (CSReset) of two consecutive code-groups, followed by an ESD of two consecutive codegroups, is generated, after which the transmission of idle or control mode is resumed. If a PMA_TXMODE.indicate message has the value SEND_Z, PCS Transmit passes a vector of zeros at each symbol period to the PMA via the PMA_UNITDATA.request primitive.

55.3.1.3 PCS Transmit function Continued

If a PMA_TXMODE.indicate message has the value SEND_I, PCS Transmit generates sequences of codegroups according to the encoding rule in training mode. Special code-groups that use only the values **TBD** are transmitted in this case. Training mode encoding also takes into account the value of the parameter loc_rcvr_status. By this mechanism, a PHY indicates the status of its own receiver to the link partner during idle transmission.

In the normal mode of operation, the PMA_TXMODE.indicate message has the value SEND_N, and the PCS Transmit function uses an **TBD** coding technique to generate at each symbol period code-groups that represent data, control or idle based on the code-groups defined in **TBD**. During transmission of data, the TXD<?:0> bits are scrambled by the PCS using a side-stream scrambler, then encoded into a code-group of **TBD** symbols and transferred to the PMA. During data encoding, PCS Transmit utilizes a **TBD** convolutional encoder.

The transition from idle or carrier extension to data is signaled by inserting a SSD, and the end of transmission of data is signaled by an ESD. Further code-groups are reserved for signaling the assertion of TX_ER within a stream of data, carrier extension, CSReset, and other control functions. During idle and carrier extension encoding, special code-groups with symbol values restricted to the set **TBD** are used. These code-groups are also generated using the transmit side-stream scrambler. However, the encoding rules for the idle, SSD, and carrier extend code-groups are different from the encoding rules for data, CSReset, CSExtend, and ESD code-groups. During idle, SSD, and carrier extension, the PCS Transmit function reverses the sign of the transmitted symbols. This allows, at the receiver, sequences of code-groups that represent data, CSReset, CSExtend, and ESD to be easily distinguished from sequences of code-groups that represent SSD, carrier extension, and idle.

55.3.1.3 PCS Transmit function Continued

PCS encoding involves the generation of the **TBD**-bit words Sxn[3:0], Syn[3:0], and Sgn[3:0] from which the **TBD** symbols (An, Bn, Cn, Dn) are obtained. The **TBD**-bit words Sxn[3:0], Syn[3:0], and Sgn[3:0] are determined from sequences of pseudorandom binary symbols derived from the transmit side-stream scrambler.

55.3.1.3.1 Side-stream scrambler polynomials

The PCS Transmit function employs side-stream scrambling. If the parameter config provided to the PCS by the PMA PHY Control function via the PMA_CONFIG.indicate message assumes the value MASTER, PCS Transmit shall employ

$$g_M(x) = 1 + x^{13} + x^{33}$$

as transmitter side-stream scrambler generator polynomial. If the PMA_CONFIG.indicate message assumes the value of SLAVE, PCS Transmit shall employ

$$g_S(x) = 1 + x^{20} + x^{33}$$

as transmitter side-stream scrambler generator polynomial. An implementation of master and slave PHY side-stream scramblers by linear-feedback shift registers is shown in Figure ?–6. The bits stored in the shift register delay line at time n are denoted by Scrn[32:0]. At each symbol period, the shift register is advanced by one bit, and one new bit represented by Scrn[0] is generated. The transmitter side-stream scrambler is reset upon execution of the PCS Reset function. If PCS Reset is executed, all bits of the 33-bit vector representing the side-stream scrambler state are arbitrarily set. The initialization of the scrambler state is left to the implementor. In no case shall the scrambler state be initialized to all zeros.

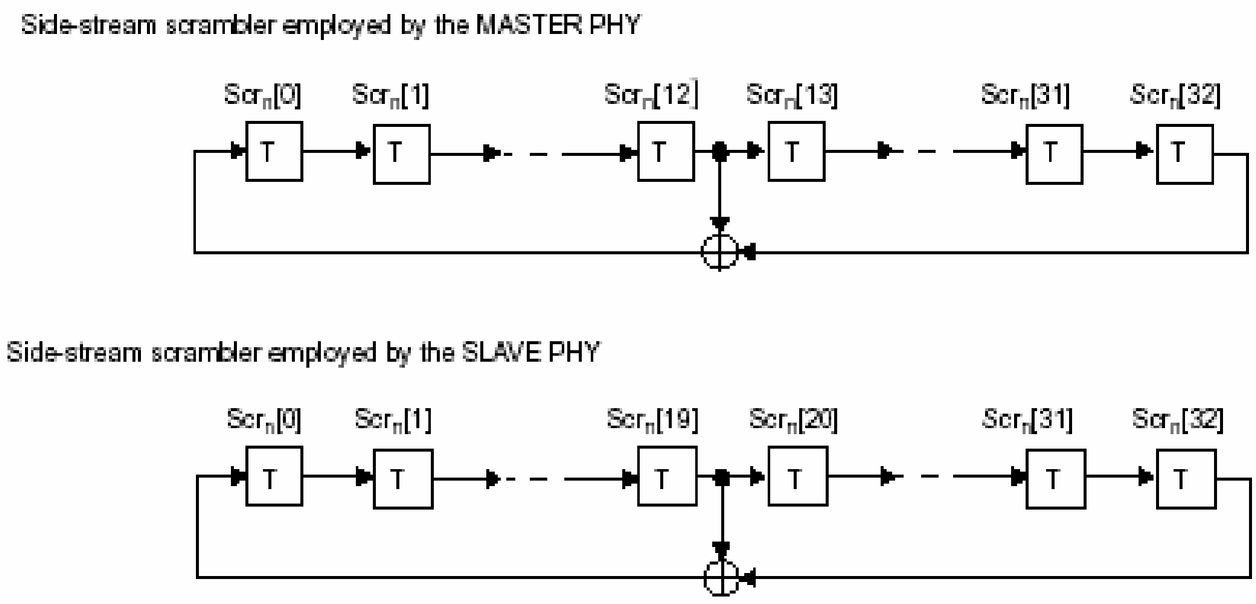


Figure ? –6— A realization of side-stream scramblers by linear feedback shift registers