data recovery in noisy environments. The 4B/5B mapping and the scrambler are contained in the PCS (see 147.3) while the DME encoder/decoder is contained in the PMA (see 147.4).

147.2 Service primitives and interfaces

The 10BASE-T1S PHY shall use the service primitives and interfaces in 40.2, with exception of the following clarifications and differences noted in this section. Figure 147–2 shows the relationship of the service primitives and interfaces used by the 10BASE-T1S PHY.

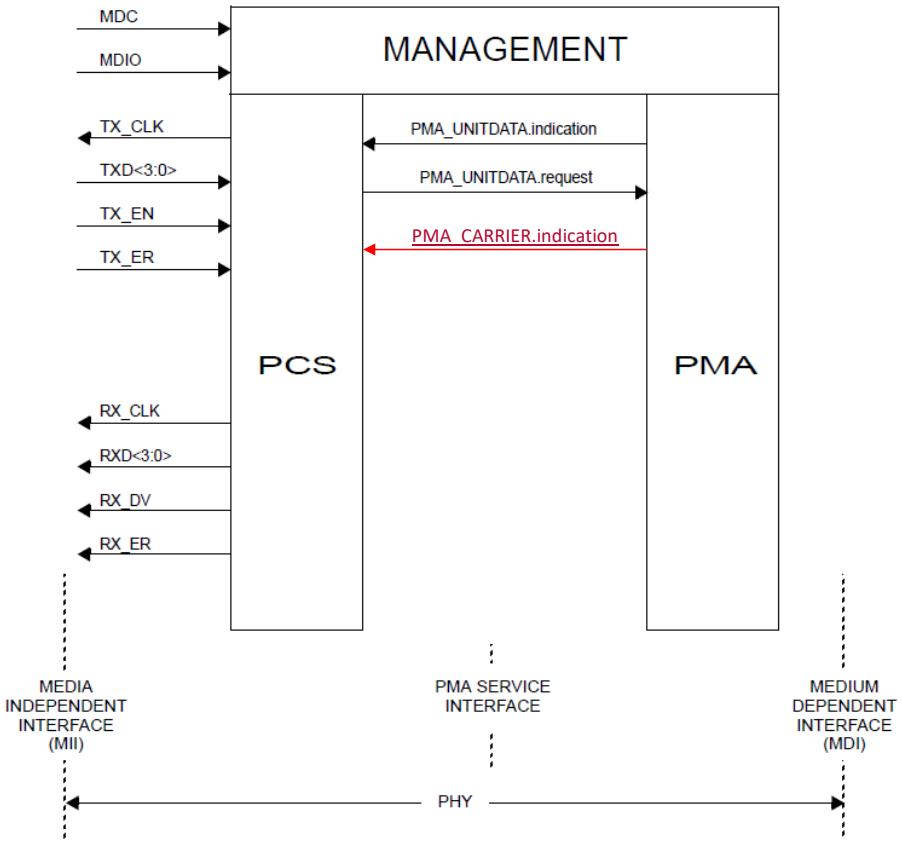

Figure 147–2—10BASE-T1S PHY interfaces

The 10BASE-T1S PHY uses the Media Independent Interface (MII) as specified in Clause 22.

Commented [PB1]: #649: CRS usage
Add PMA primitive to generate CRS by energy detection

As shown in Figure 147–2, 10BASE-T1S uses the following service primitives to exchange symbol vectors, status indications, and control signals across the PMA service interface:

PMA_UNITDATA.indication (rx_sym)
PMA_UNITDATA.request (tx_sym)
PMA_CARRIER.indication(pma_crs)

147.2.1 Mapping of PMA_CARRIER.indication

Reports whether a signal compatible with DME encoding rules specified in 147.4.2 is detected on the medium.

147.2.1.1 Function

Maps the primitive PMA_CARRIER.indication to the MII CRS signal.

147.2.1.2 Semantic of the service primitive

PMA_CARRIER.indication(pma_crs)

The pma_crs parameter can take one of two values: CARRIER_ON or CARRIER_OFF.
The pma_crs parameter is set to CARRIER_ON if a signal compatible with DME encoding rules specified in 147.4.2 is present on the medium. Otherwise the pma_crs parameter is set to CARRIER_OFF.

147.2.1.3 When Generated

The PMA_CARRIER.indication primitive is generated continuously by the PMA sublayer.

Commented [PB2]: #649: CRS usage
Add PMA primitive to generate CRS by energy detection

147.3 Physical Coding Sublayer (PCS) functions

The Physical Coding Sublayer (PCS) consists of PCS Reset, PCS Transmit, and PCS Receive functions as shown in Figure 147–3. The PCS Reset function is explained in 147.3.1, the PCS Transmit function is explained in 147.3.2, the PCS Receive function is explained in 147.3.3, and the PCS Loopback function is explained in 147.3.4.

147.3.1 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 shall set pcs_reset = ON while any of the above reset conditions holds 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.

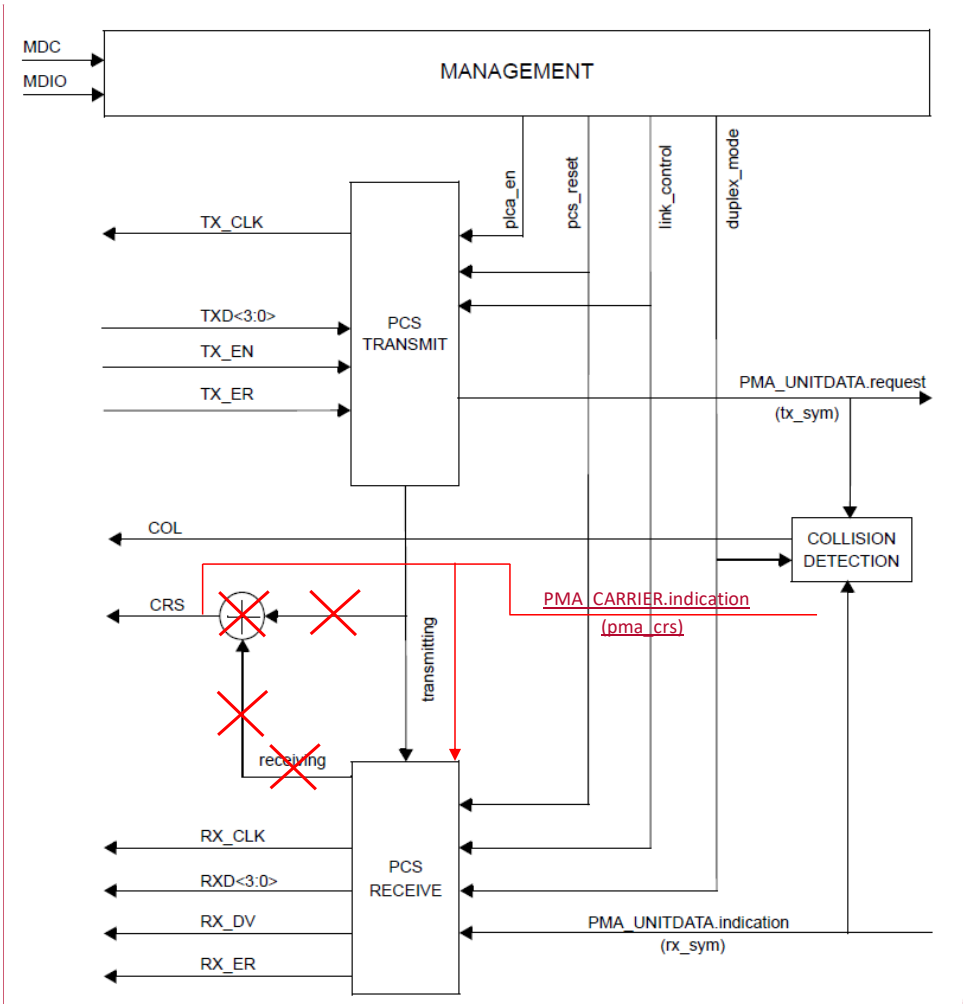

Figure 147–3—PCS reference diagram

Commented [PB3]: #649: CRS usage
Modify figure to indicate that CRS is generated out of energy detection in the PMA

147.3.2 PCS Transmit

147.3.2.1 PCS Transmit overview

The PCS Transmit function shall conform to the PCS Transmit state diagram in Figure 147–4 and Figure 147–5, and the associated state variables, functions, timers and messages.

At each symbol period, PCS Transmit generates a symbol tx_sym conveyed to the PMA through the PMA_UNITDATA.request service primitive, where tx_sym is a five-bit vector. The PMA encodes tx_sym, LSB first, into a DME stream over the wire pair BI_DA at a nominal symbol clock frequency specified in 147.5.4.5.

Upon assertion of TX_EN, the PCS Transmit function passes a group of two SYNC symbols to the PMA, followed by two SSD symbols which replaces the first 16 bits of the packet preamble. Following the second SSD, TXD<3:0> is encoded into 5B symbols using the encoding rules specified in Table 147–1, until TX_EN is deasserted.

Following the de-assertion of TX_EN, the PCS Transmit generates a special code ESD, followed by either ESDOK or ESDERR when a transmit error is encountered.

The 10BASE-T1S has one special 5B symbol 'I' (binary vector of 1,1,1,1,1) which represents SILENCE. SILENCE represents an indication for the PMA to change the PMD state according to 147.4.2.

147.3.2.2 Variables

pcs_reset

The pcs_reset parameter set by the PCS Reset function.
Values: ON or OFF

pcs_txen

The TX_EN signal of the MII as specified in 22.2.2.3.
When set to FALSE transmission is disabled.
When set to TRUE transmission is enabled.
Values: TRUE or FALSE

pcs_txer

The TX_ER signal of the MII as specified in 22.2.2.5.
When set to FALSE it indicates a non-errored transmission.
When set to TRUE it indicates an errored transmission.
Values: TRUE or FALSE

pcs_txd

The TXD signal of the MII as specified in 22.2.2.4.
This signal represents a 4B data nibble to be transmitted.

~~plca_en~~

~~The plca_en signal, described in 148.4.5.2, controls the optional PLCA function in the PCS. When PLCA is not implemented, plca_en shall be set to OFF. If MDIO registers are implemented, the plca_en may be set by MDIO register 3.2291.13.~~
~~Values: ON or OFF~~

Commented [PB4]: #283: plca_en
Remove plca_en description as it is not used anymore in this clause, as comment requests

tx_cmd

5B symbol to be transmitted when the PCS Transmit function is in SILENT state. The tx_cmd variable is assigned according to PLCA RS signaling over MII interface, as defined in 22.2.2.4, 148.4.3.1.1, and 148.4.3.1.2. The following mapping shall be used:
- tx_cmd <= 'N' when a BEACON request is asserted
- tx_cmd <= 'J' when a COMMIT request is asserted
- tx_cmd <= 'I' otherwise.
When PLCA capabilities are not supported or disabled, tx_cmd shall be set to the special 5B symbol 'I' (binary vector of 1,1,1,1,1) representing SILENCE.

tx_sym

5B symbol to transmit, generated from the MII data or directly passed from tx_cmd in SILENT state when optional PLCA reconciliation sublayer is implemented.

transmitting

This variable is set in the PCS Transmit state, as described in Figure 147–4.
When this variable is set to TRUE it indicates a transmission is ongoing.
Values: TRUE or FALSE

err

This variable is set in the PCS Transmit state, as described in Figure 147–4 and Figure 147–5.
This variable is used to detect and latch a pcs_txer = TRUE condition during data transmission; if such error is detected, an ESDERR symbol is sent at the end of transmission.
Values: TRUE or FALSE

link_control

This variable is generated by management or set by default. When set to FALSE all PCS functions are switched off and no data can be sent or received.
Values: TRUE or FALSE

txcnt

General purpose counter for PCS transmit function.

SYNC

5B symbol defined as ‘J’ in 4B/5B encoding.

SSD

5B symbol defined as ‘H’ in 4B/5B encoding.

ESD

5B symbol defined as ‘T’ in 4B/5B encoding.

ESDERR

5B symbol defined as ‘K’ in 4B/5B encoding.

ESDOK

5B symbol defined as ‘R’ in 4B/5B encoding.

SILENCE

5B symbol defined as ‘I’ in 4B/5B encoding.

147.3.2.3 Function

ENCODE

In the PCS transmit process, this function takes as its arguments four bits of input data, scrambles it as defined in 147.3.2.5 and returns the corresponding 5B symbol as defined in Table 147–1.

Table 147–1—4B/5B Encoding

Name	4B	5B	Special function
0	0000	11110	
1	0001	01001	
2	0010	10100	
3	0011	10101	
4	0100	01010	
5	0101	01011	
6	0110	01110	
7	0111	01111	
8	1000	10010	
9	1001	10011	
A	1010	10110	
B	1011	10111	
C	1100	11010	
D	1101	11011	

E	1110	11100	
F	1111	11101	
I	N/A	11111	SILENCE
J	N/A	11000	SYNC
K	N/A	10001	ESDERR
T	N/A	01101	ESD
R	N/A	00111	ESDOK
H	N/A	00100	SSD
N	N/A	01000	BEACON

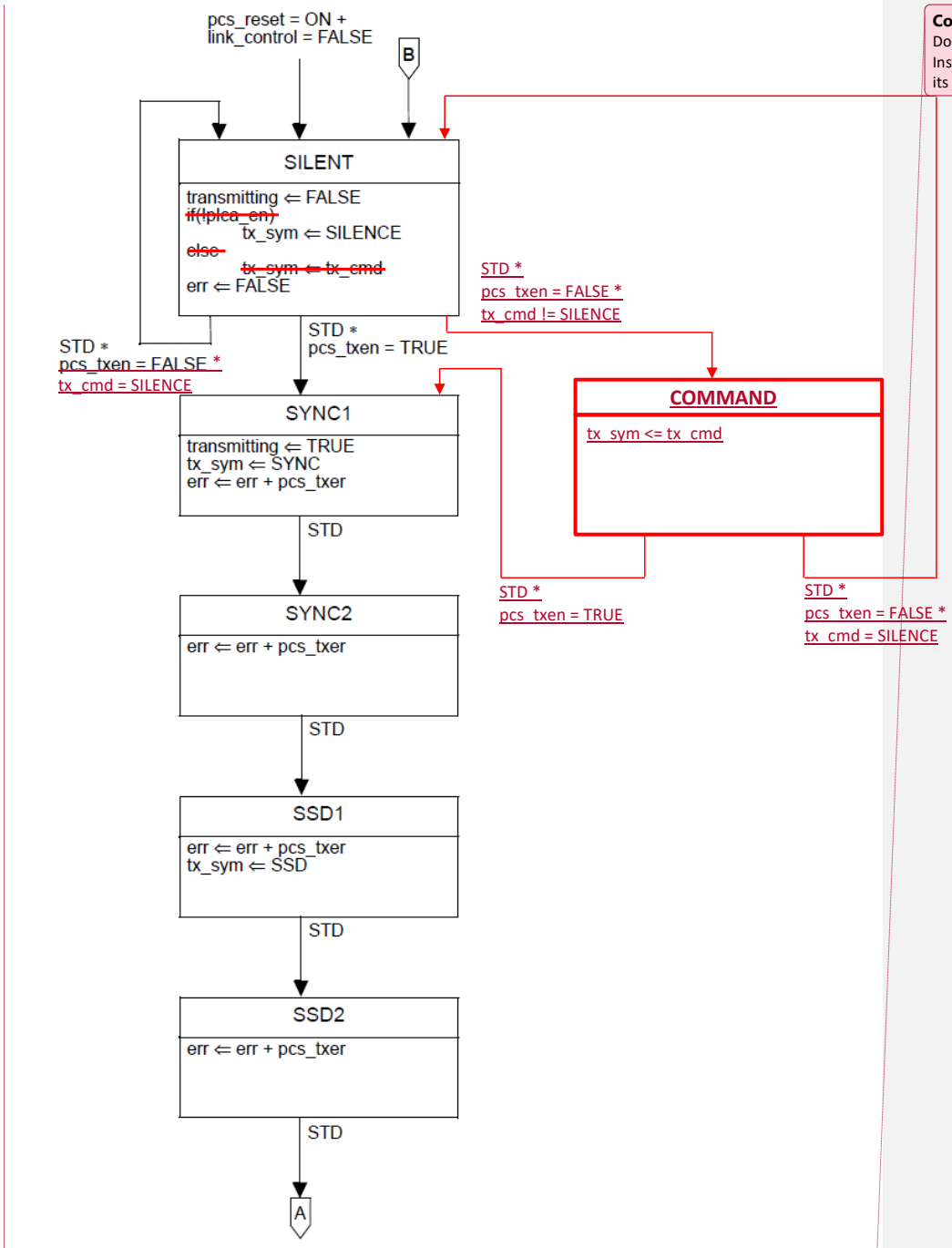

Figure 147–4—PCS Transmit state diagram (1 of 2)

Commented [PB5]: #283: plca_en
Don't use plca_en in C147 as requested by the comment. Instead, rely on tx_sym to be set appropriately, letting RS do its job.

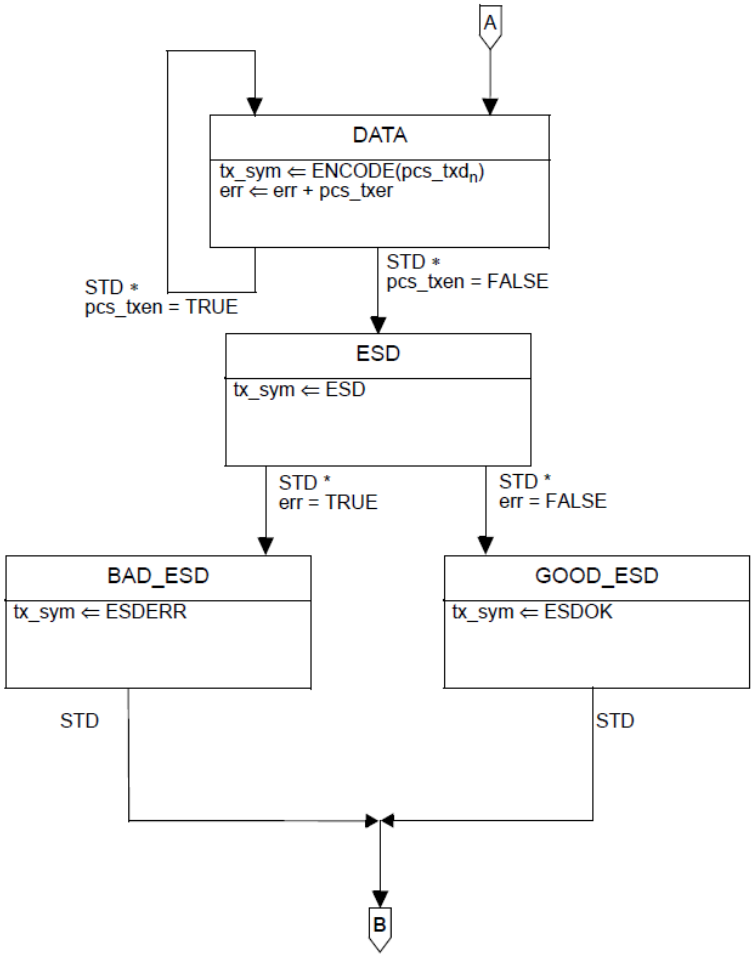

Figure 147–5—PCS Transmit state diagram (2 of 2)

147.3.2.4 Abbreviations

STD

Alias for 5B symbol timer done, synchronous to PCS TX clock.

147.3.2.5 Self-synchronizing scrambler

The PCS Transmit function shall implement multiplicative scrambling using the following generator polynomial .

An implementation of self-synchronizing scrambler by linear-feedback shift register is shown in figure Figure 147–6. The bits stored in the shift register delay line at time n are denoted by $Scr_n[16:0]$. At every MII clock cycle, for each bit of TXD[3:0] the scrambler is advanced by one bit, and the output bit $Sd_n[i]$ represented by the exclusive-OR of $Scr_n[13]$, $Scr_n[16]$ and TXD[i] is shifted in as a new $Scr_n[0]$, with i ranging from 0 to 3 (i.e. LSB first). The scrambler is reset upon execution of the PCS Reset function. If the PCS Reset is executed, all bits of the 17-bit vector representing the self-synchronizing scrambler state are arbitrarily set. The initialization of the scrambler state is left to the implementer. In no case shall the scrambler state be initialized to all zeroes.

147.3.3 PCS Receive

147.3.3.1 PCS Receive overview

The PCS Receive function shall conform to the PCS Receive state diagram in Figure 147–8 and Figure 147–9, and associated state variables.

Note: A JAB state machine as the one defined for the 10BASE-T1L PHY in Clause 146 is not required for the 10BASE-T1S PHY because even in case of mis-detection of the ESD special symbol, the actual end of a transmission can still be detected by the PMA exploiting the absence of DME activity on the line. In fact, during idle period (i.e. when no data is being transmitted), the PMD is either driving a constant zero voltage level or put into high impedance state, depending on the operating mode (see 147.5.2).

The finite state machine defined in Figure 147–8 is triggered by the reception of a SYNC symbol from the PMA Receive function and waits for two SSD symbols to start regenerating the packet preamble whose start has been replaced with the SYNC, SYNC, SSD, SSD sequence by the PCS Transmit functions as described in Figure 147–4. After the second SSD is received, the PCS Receive function discards the next nine symbols which shall instead be used to achieve lock of the self-synchronizing descrambler.

During the descrambler locking time, the special value 5 is conveyed to the MII via the pcs_rxd variable in order to rebuild the original preamble transmitted by the MAC.

The DATA state, in which 5B symbols are decoded into MII data, is left when ESD followed by either ESDOK or ESDERR symbol is encountered or when the PMA detects SILENCE on the media (e.g. the transmitter prematurely stops data transmission).

The variables, functions, and timers used in Figure 147–8 are defined as below. For the definition of pcs_reset, SILENCE, SYNC, SSD, ESD, ESDOK and ESDERR see 147.3.2.2.

147.3.3.2 Variables

receiving

This variable is set in the PCS Receive state, as described in Figure 147–8 and Figure 147–9. When it is set to TRUE it indicates that a data reception is ongoing. Values: TRUE or FALSE

duplex_mode

This variable indicates whether the PHY is configured for full-duplex operation (DUPLEX_FULL) or half-duplex operation (DUPLEX_HALF). This variable is set after bit 8 in MDIO register 0 defined in Table 22-7.

precnt

Counter for preamble regeneration.

pcs_rxdv

The RX_DV signal of the MII as specified in 22.2.2.7.

pcs_rxer

The RX_ER signal of the MII as specified 22.2.2.10.

pcs_rxd

PCS decoded data synchronous to RX_CLK.

RXn

Received 5b symbol generated by PMA receive at time n.

SILENCE

The 5B symbol defined as 'I' in 4B/5B encoding.

147.3.3.3 Functions

DECODE

In the PCS Receive process, this function takes as its arguments one 5B symbol, decodes the corresponding nibble as defined in Table 147–1, descrambles it as defined in 147.3.3.5 and returns the descrambled result as defined in 147.3.3.5. If a violation of the encoding rules is detected, PCS Receive asserts the signal RX_ER for at least one symbol period.

147.3.3.4 Abbreviations

RSCD Alias for Receive Symbol Conversion Done, synchronous to PCS RX clock

147.3.3.5 Self-synchronizing descrambler

The PCS Receive function shall descramble the 5B/4B decoded data stream and return the proper nibble for generation of RXD[3:0] to the MII. The descrambler shall employ the polynomial defined in 147.3.2.5. The implementation of the self-synchronizing descrambler by linear-feedback shift register is shown in Figure 147–7. The bits stored in the shift register delay line at time n are denoted by $Dcr_n[16:0]$. At every MII clock cycle, each bit of $Dr_n[3:0]$ is shifted in as new $Dcr_n[0]$ and the descrambler is advanced by one bit. The output bit RXD[i] represented by the exclusive OR of $Dcr_n[13]$, $Dcr_n[16]$ and $Dr_n[i]$ is generated, with i ranging from 0 to 3 (i.e. LSB first). The descrambler is reset upon execution of the PCS Reset function. If PCS Reset is executed, all the bits of the 17-bit vector representing the self-synchronizing descrambler state are arbitrarily set. The initialization of the descrambler state is left to the implementer.

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147.3.4 PCS Loopback

The PCS shall be placed in loopback mode when the loopback bit in MDIO register 3.0.14, defined in 45.2.3.1.2, is set to a one (or PCS loopback mode is enabled by a similar functionality if MDIO is not implemented). In this mode, the PCS shall accept data on the transmit path from the MII and return it on the receive path to the MII. Additionally, the PHY receive circuitry shall be isolated from the network medium, and the assertion of TX_EN at the MII shall not result in the transmission of data on the network medium.

147.3.5 Collision detection

When operating in half-duplex mode, the 10BASE-T1S PHY shall detect physical collisions on the media during data transmission. When collisions are detected, the PHY shall assert the signal COL on the MII for the duration of the collision or until TX_EN signal is FALSE.

A collision can be detected by monitoring the rx_sym parameter conveyed through the PMA_UNITDATA.indication primitive for a SYNC, SSD symbol sequence and verify matching against the transmitted symbol sequence after the SSD symbol. A collision results in a mismatch in the symbol sequence.

147.3.6 Carrier sense

When operating in half-duplex mode, the 10BASE-T1S PHY shall sense when the media is busy and convey this information to the MAC asserting the signal CRS on the MII as specified in 22.2.2.11.

~~CRS is generated by PCS Receive as the logical OR of the "transmitting" and "receiving" variables.~~
CRS is generated by mapping the PMA_CARRIER.indication(pma_crs) primitive to the MII signal CRS.
CRS shall be asserted when the pma_crs parameter is CARRIER_ON.
CRS shall be de-asserted when the pma_crs parameter is CARRIER_OFF.

Commented [PB6]: #649: CRS usage
Generate CRS out of the PMA_CARRIER.indication primitive which relies on energy detection instead of decoding a valid preamble.

147.3.7 Optional support for PLCA Reconciliation Sublayer

When PLCA capabilities defined in Clause 148 are supported, the following applies.

147.3.7.1 Generation of BEACON indication

In compliance to 148.4.4.2.1, when PLCA RS operations are supported and enabled, the PHY shall notify the RS of a received BEACON indication by the means of MII interface as specified in 22.2.2.8.

When a sequence of at least two consecutive 'N' symbols is received, the MII signals RX_DV, RX_ER and RXD shall be set to the BEACON indication as shown in Table 22–2, overriding the current state. Override shall cease as soon as the currently received symbol is anything other than a 'N' code.

147.3.7.2 Generation of COMMIT indication

In compliance to 148.4.4.2.2, when PLCA RS operations are supported and enabled, the PHY shall notify the RS of a received COMMIT indication by the means of MII interface as specified in 22.2.2.8.

When a sequence of at least two consecutive 'J' symbols is received, the MII signals RX_DV, RX_ER and RXD shall be set to the COMMIT indication as shown in Table 22–2, overriding the current state. Override shall cease as soon as the currently received symbol is anything other than a 'J' code.

~~147.3.7.3 Optional generation of early receive indication~~

~~In compliance to 148.4.4.2.4, when PLCA RS operations are supported and enabled, the PHY may notify the RS of an early receive indication by the means of MII interface as specified in 22.2.2.11 and 22.2.2.12.~~

~~The generation of the early receive indication is optional and left to the implementer as long as the requirements defined in the mentioned clauses are met.~~

Commented [PB7]: #649: CRS Usage
Remove PLCA ERI function as a consequence of defining CRS as energy detection.

147.4 Physical Medium Attachment (PMA) Sublayer

The reference diagrams do not explicitly show the PMA Reset function.

The PMA couples messages from the PMA service interface specified in 147.3.1 onto the 10BASE-T1S physical medium. The PMA provides both full duplex and half duplex communications to and from medium employing Differential Manchester Encoding. The interface between PMA and the baseband medium is the Medium Dependent Interface (MDI), which is specified in 147.9.

147.4.1 PMA Reset function

The PMA Reset function shall be executed whenever one of the two following conditions occur:

a) Power on (see 36.2.5.1.3).
b) The receipt of a request for reset from the management entity.

147.4.2 PMA Transmit function

During transmission, PMA_UNITDATA.request conveys to the PMA using tx_sym the value of the symbols to be sent over the single transmit pair.