78. Energy-Efficient Ethernet (EEE)

78.1 Overview

78.1.3 Reconciliation sublayer operation

78.1.3.3 PHY LPI operation

78.1.3.3.1 PHY LPI transmit operation

Insert a row for 10BASE-T1L and 10BASE-T1S after 10BASE-Te in Table 78–1 as follows (unchanged rows not shown):

Table 78–1—Clauses associated with each PHY or interface type

PHY or interface type	Clause
…	…
10BASE-T1L	146
10BASE-T1S	147
…	…

78.2 LPI mode timing parameters description

Insert a row for 10BASE-T1L at the beginning of Table 78–2 as follows (unchanged rows not shown):

Table 78–2—Summary of the key EEE parameters for supported PHYs

PHY or interface type	T_S (µs)		T_Q (µs)		T_R (µs)	
	Min	Max	Min	Max	Min	Max
10BASE-T1L	200	210	2000	2100	200	210
…	…	…	…	…	…	…

78.5 Communication link access latency

Insert a row for 10BASE-T1L at the beginning of Table 78–4 (as modified by IEEE Std 802.3by-2016) as follows (unchanged rows not shown):

Table 78–4—Summary of the LPI timing parameters for supported PHYs

PHY or interface type	Case	Tw_sys_tx (min) (µs)	Tw_phy (min) (µs)	Tphy_shrink_tx (max) (µs)	Tphy_shrink_rx (max) (µs)	Tw_sys_rx (min) (µs)
10BASE-T1L		220	220	10	220	220
…	…	…	…	…	…	…

Add the following text to Clause 146 (and renumber the following chapters):

146.1.2.3 EEE capability

A 10BASE-T1L PHY may optionally support the EEE capability, as described in 78.3. The EEE capability is a mechanism by which 10BASE-T1L PHYs are able to reduce power consumption during periods of low link utilization. PHYs can enter the LPI mode of operation after completing training. Each direction of the full duplex link is able to enter and exit the LPI mode independently, supporting symmetric and asymmetric LPI operation. This allows power savings when only one side of the full duplex link is in a period of low utilization. The transition to or from LPI mode shall not cause any MAC frames to be lost or corrupted.

In the transmit direction the transition to the LPI transmit mode begins when the PCS transmit function detects an "Assert Low Power Idle" condition on the MII. If this condition is detected, tx_lpi_active is set true and shortly after this the PHY asserts the loc_lpi_req signal, which is transmitted within the IDLE symbol stream to the remote PHY. This sleep signal indicates to the link partner that the transmit function of the PHY is entering the LPI transmit mode. After the transmission of the sleep indications, the transmit function of the local PHY enters the LPI transmit mode. While the transmit function is in the LPI mode the PHY may disable data path and control logic to save additional power. Periodically the transmit function of the local PHY transmits refresh frames that may be used by the link partner to update adaptive filters and timing circuits. The refresh cycle continues until the PCS function detects a condition that is not Assert Low Power Idle on the MII. This condition signals to the PHY that the LPI transmit mode should end. The PHY is now starting to transmit an IDLE symbol stream, where loc_lpi_req is de-asserted, thus indicating to the remote PHY, that this PHY is going back to normal transmit mode again.

Support for EEE capability is advertised during Auto-Negotiation. See Annex 98C.5 for details. Transitions to and from the LPI transmit mode are controlled via MII signaling. Transitions to and from the LPI receive mode are controlled by the link partner using sleep and wake signaling.

Add the following additional option to the Chapter Signaling (currently 146.1.2.3, when adding above chapter, then 146.1.2.4):

g) Optionally, ability to signal to the remote PHY that the transmitting PHY is entering the LPI mode or exiting the LPI mode and returning to normal power operation.

Add the three primitives PMA_RX_LPI_STATUS.request, PMA_TX_LPI_STATUS.request (direction from PCS to PMA) and PMA_LPI_STATUS.indication (direction from PMA to PCS) to Figure 146-2 (dashed lines as they are optional) and add the following note to Figure 146-2:

NOTE—Service interface primitives shown with dashed lines are optional.

Add the following text at the end of chapter 146.2

EEE-capable PHYs additionally support the following service primitives:

PMA_RX_LPI_STATUS.request (rx_lpi_active)
PMA_TX_LPI_STATUS.request (tx_lpi_active)
PMA_LPI_STATUS.indication (loc_lpi_req)

Add the following chapters to Clause 146:

146.2.9 PMA_PCS_RX_LPI_STATUS.request

When the PHY supports the EEE capability this primitive is generated by the PCS receive function to indicate the status of the receive link of the local PHY. The parameter PMA_ RX_LPI_STATUS.request conveys to the PMA receive function and the PMA PHY control function information regarding whether the PCS receive function is in the LPI receive mode.

146.2.9.1 Semantics of the primitive

PMA_RX_LPI_STATUS.request (rx_lpi_active)

The rx_lpi_active parameter can take on one of two values of the following form:
TRUE: The PCS receive function is in the LPI receive mode.
FALSE: The PCS receive function is not in the LPI receive mode.

146.2.9.2 When generated

The PCS generates PMA_RX_LPI_STATUS.request messages to indicate a change in the rx_lpi_active variable as described in Figure 146-8.

146.2.9.3 Effect of receipt

The receiver may adjust the link training and clock recovery while being in low power idle mode. Additionally checking of the descrambler status in the PHY control state diagram is suppressed, as the receiver is disabled.

146.2.10 PMA_TX_LPI_STATUS.request

When the PHY supports the EEE capability this primitive is generated by the PCS transmit function to indicate the status of “Assert Low Power Idle” on the MII. The parameter PMA_TX_LPI_STATUS.request conveys to the PMA PHY control function information regarding whether the PCS transmit function is receiving “Assert Low Power Idle” on the MII.

146.2.10.1 Semantics of the primitive

PMA_TX_LPI_STATUS.request (tx_lpi_active)

The tx_lpi_active parameter can take on one of two values of the following form:
TRUE: The PCS transmit function is receiving “Assert Low Power Idle” on the MII.
FALSE: The PCS transmit function is not receiving “Assert Low Power Idle” on the MII.

146.2.10.2 When generated

The PCS generates PMA_TX_LPI_STATUS.request messages to indicate a change in the tx_lpi_active variable to the PMA PHY control function. Tx_lpi_active is set to true, if “Assert Low Power Idle” is received from the MII, otherwise it is set to false.

146.2.10.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure 146-15.

146.2.11 PMA_TX_LPI_STATUS.indication

When the PHY supports the EEE capability this primitive is generated by the PMA PHY control function to indicate a sleep or wake event. The parameter PMA_TX_LPI_STATUS.indication conveys to the PCS transmit function information regarding whether the PHY should indicate a sleep or a wake event to the remote PHY.

146.2.10.1 Semantics of the primitive

PMA _TX_LPI_STATUS.indication (loc_lpi_req)

The loc_lpi_req parameter can take on one of two values of the following form:
TRUE: Communicate to the remote PHY that LPI mode will be entered by the local PHY.
FALSE: Communicate to the remote PHY that normal IDLE mode will be entered by the local PHY.

146.2.10.2 When generated

The PMA generates PMA_TX_LPI_STATUS.indication messages to indicate a change in the loc_lpi_req variable as described in Figure 146-15.

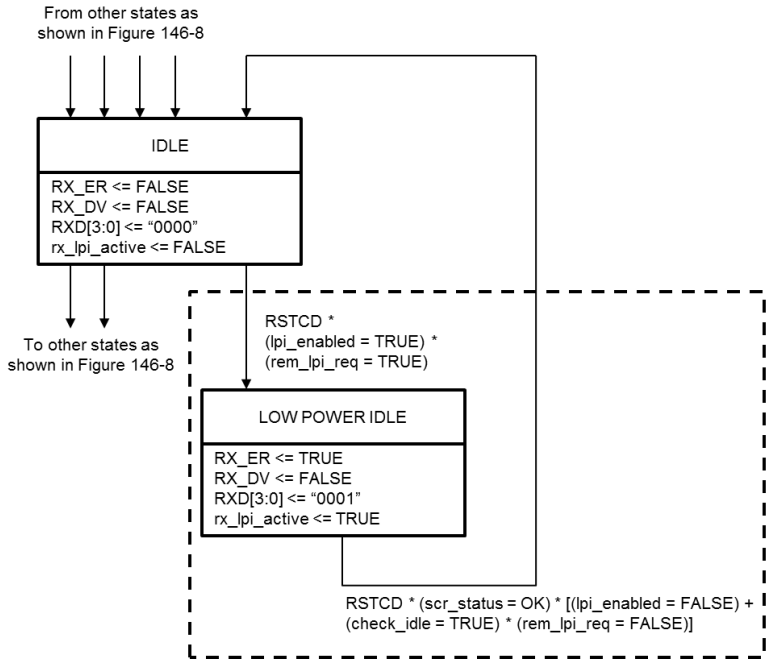
146.2.10.3 Effect of receipt

The effect of receipt of this primitive is specified in 146.3.3.2.4.

In figure 146-3 add the tx_lpi_active signal from the PCS TRANSMIT block going to the PMA Service Interface section in dashed style, add the rx_lpi_active signal from the PCS RECEIVE block going to the PMA Service Interface in dashed style, and add the following note to figure 146-3:

NOTE—Signals shown with dashed lines are optional.

Add the following LOW POWER IDLE state to Figure 146-8 (PCS receive state diagram):



Add "rx_lpi_active <= FALSE" to state IDLE of Figure 146-8 (see above drawing).

Add a note to Figure 146-8:

NOTE—States shown within dashed line area optional.

Add the following text (in alphabetical order) to the variables section in Clause 146.3.4.1.1:

lpi_enabled: This variable indicates, if Energy Efficient Ethernet is enabled for the PHY or not. If MDIO is being implemented, it reflects to bit 1.2294.10 as described in chapter 45.2.1.174a.

Values: TRUE or FALSE

rx_lpi_active: This variable indicates to the PMA receive function, if the receive state machine is in low power idle state.

Values: TRUE or FALSE

Add the following text (in alphabetical order) to the functions section in Clause146.3.4.1.2:

rem_lpi_req: The rem_lpi_req function provides a reliable detection of the received loc_lpi_req information from the remote PHY within the IDLE data stream.

Values: TRUE or FALSE

In figure 146-12 add the rx_lpi_active signal and tx_lpi_active signal from the PMA Service Interface going to the PHY CONTROL block in dashed style, add the loc_lpi_req signal from the PHY Control block to the PMA Service Interface in dashed style, add the rx_lpi_active signal from the PMA Service Interface to the PMA RECEIVE block in dashed style, and add the following note to figure 146-12:

NOTE—Signals shown with dashed lines are optional.

In figure 146-14 add the rx_lpi_active signal going to the PMA RECEIVE block in dashed style, and add the following note to figure 146-14:

NOTE—Signals shown with dashed lines are optional.

Add the following text (in alphabetical order) to the variables section in Clause 146.4.4.1:

lpi_enabled: This variable indicates, if Energy Efficient Ethernet is enabled for the PHY or not. If MDIO is being implemented, it reflects to bit 1.2294.10 as described in chapter 45.2.1.174a.

Values: TRUE or FALSE

rx_lpi_active: This variable indicates to the PMA receive function, if the receive state machine is in low power idle state.

Values: TRUE or FALSE

tx_lpi_active: This variable indicates to the PMA PHY control function, if “Assert Low Power Idle” condition on the MII is active.

Values: TRUE or FALSE

loc_lpi_req: The variable loc_lpi_req is set TRUE, if low power idle mode is requested by the PMA PHY control function.

Values: TRUE or FALSE

Add the following text (in alphabetical order) to the timers section in Clause 146.4.4.2:

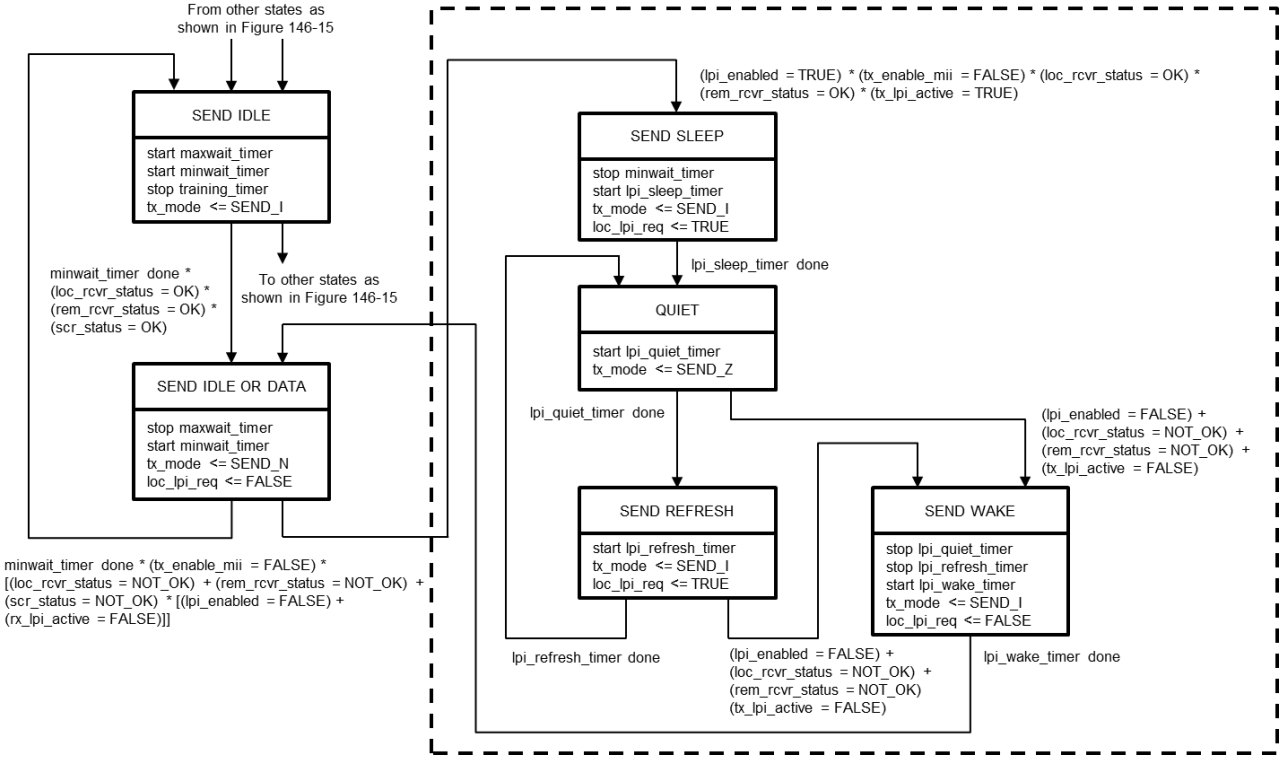
lpi_sleep_timer: A timer used to determine how long the SLEEP signal (IDLE symbols with loc_lpi_req set) is being sent, before the transmitter of the local PHY goes to sleep. The timer shall expire 205 µs ± 5 µs after being started.

lpi_quiet_timer: A timer used to determine how long the transmitter of the local PHY stays in QUIET mode, before a REFRESH is performed. The timer shall expire 2050 µs ± 50 µs after being started.

lpi_refresh_timer: A timer used to determine how long the REFRESH signal is being sent to the remote PHY. The timer shall expire 205 µs ± 5 µs after being started.

lpi_wake_timer: A timer used to determine how long the WAKE signal is being sent to the remote PHY. The timer shall expire 205 µs ± 5 µs after being started.

Modify state machine in Figure 146-15 (PMA PHY Control state diagram) in the following way:



Add "loc_lpi_req <= FALSE" to state SEND IDLE or DATA of Figure 146-15 (see above drawing).

Add a note to Figure 146-15:

NOTE—States shown within dashed line area optional.