Observations regarding Energy Efficient 1000BASE-KX

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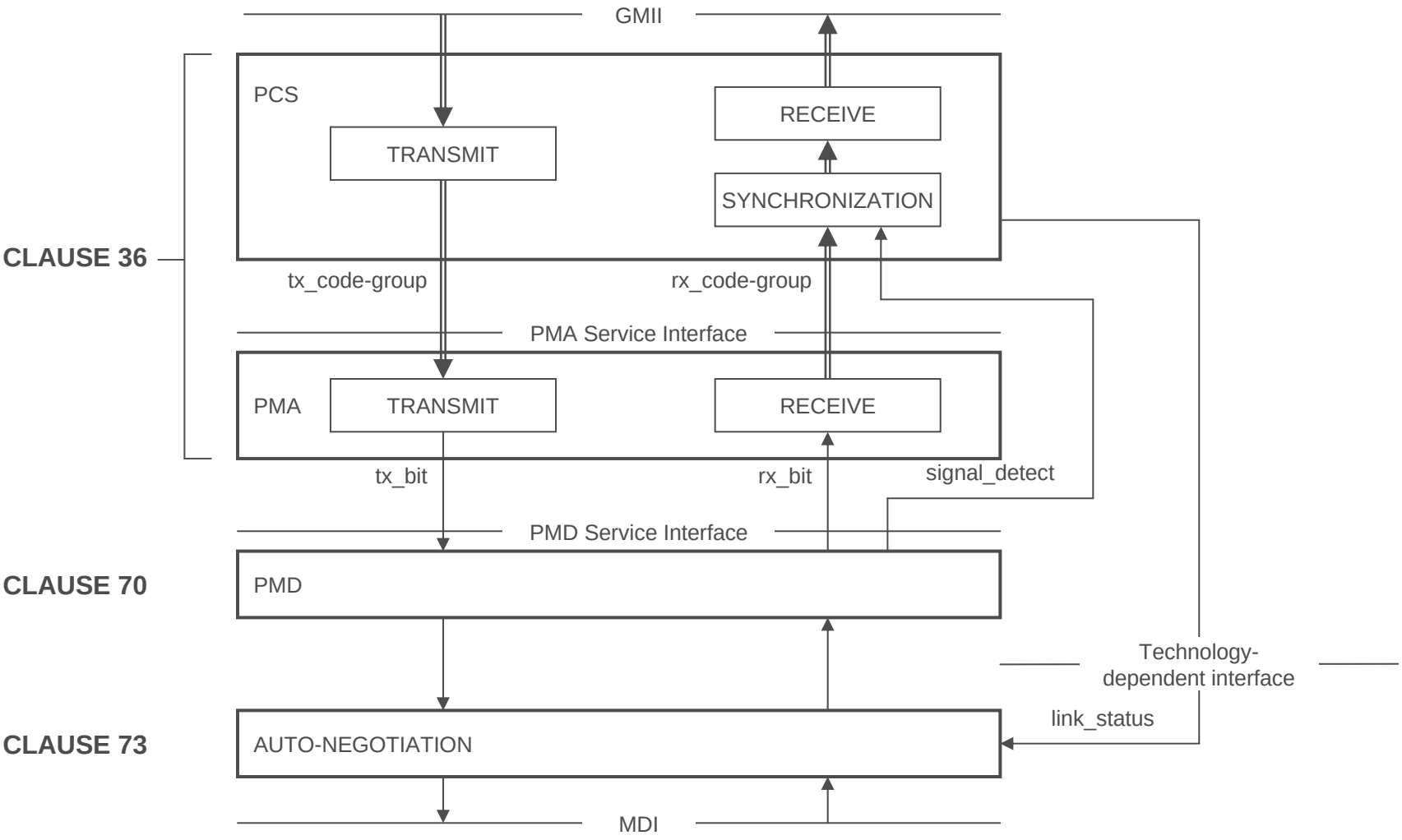
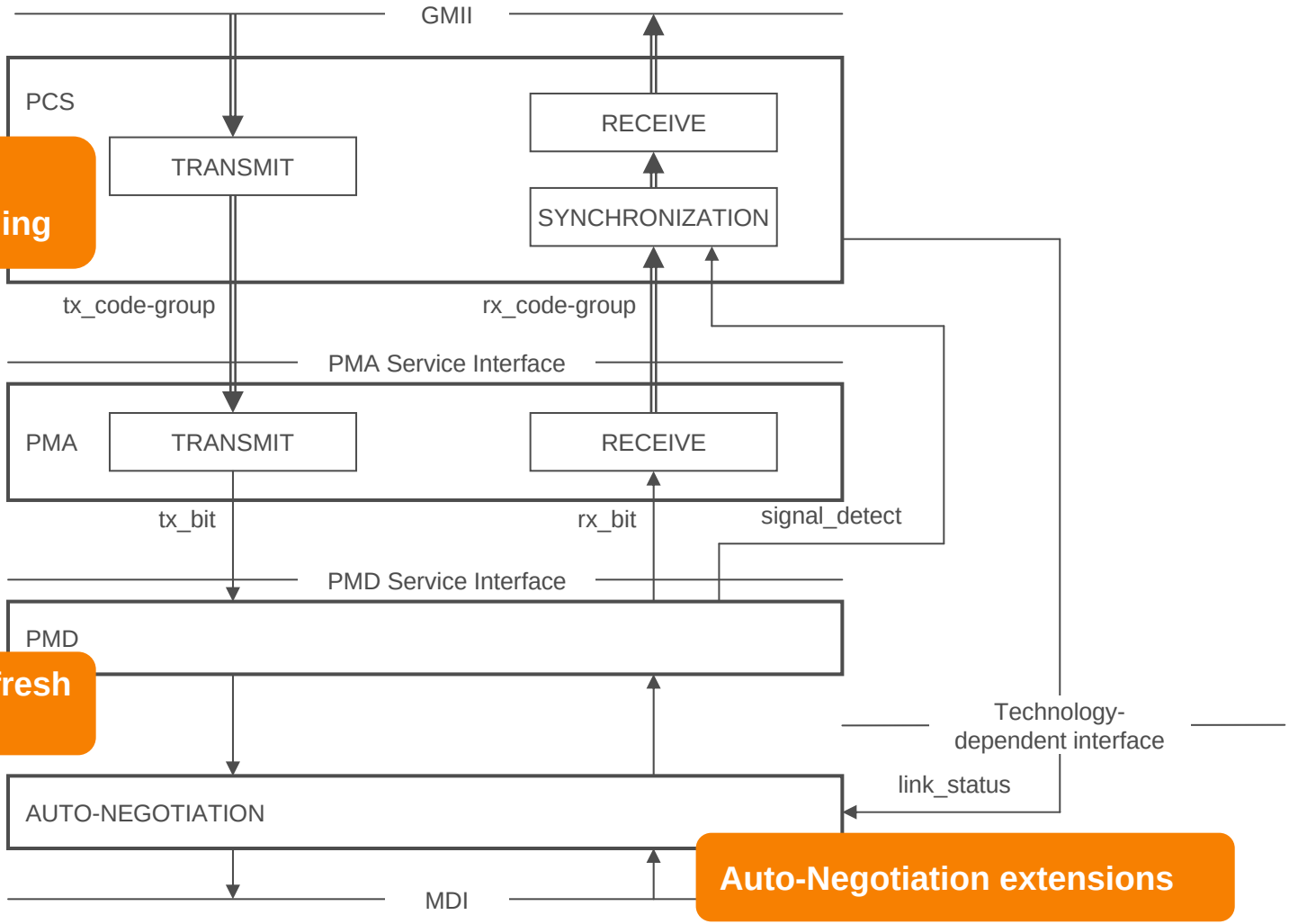
1000BASE-KX layer model



Scope of changes for 1000BASE-KX EEE

Low-power idle encoding and decoding



Support for quiet-refresh cycles

Auto-Negotiation extensions

Summary of issues with Draft 1.0

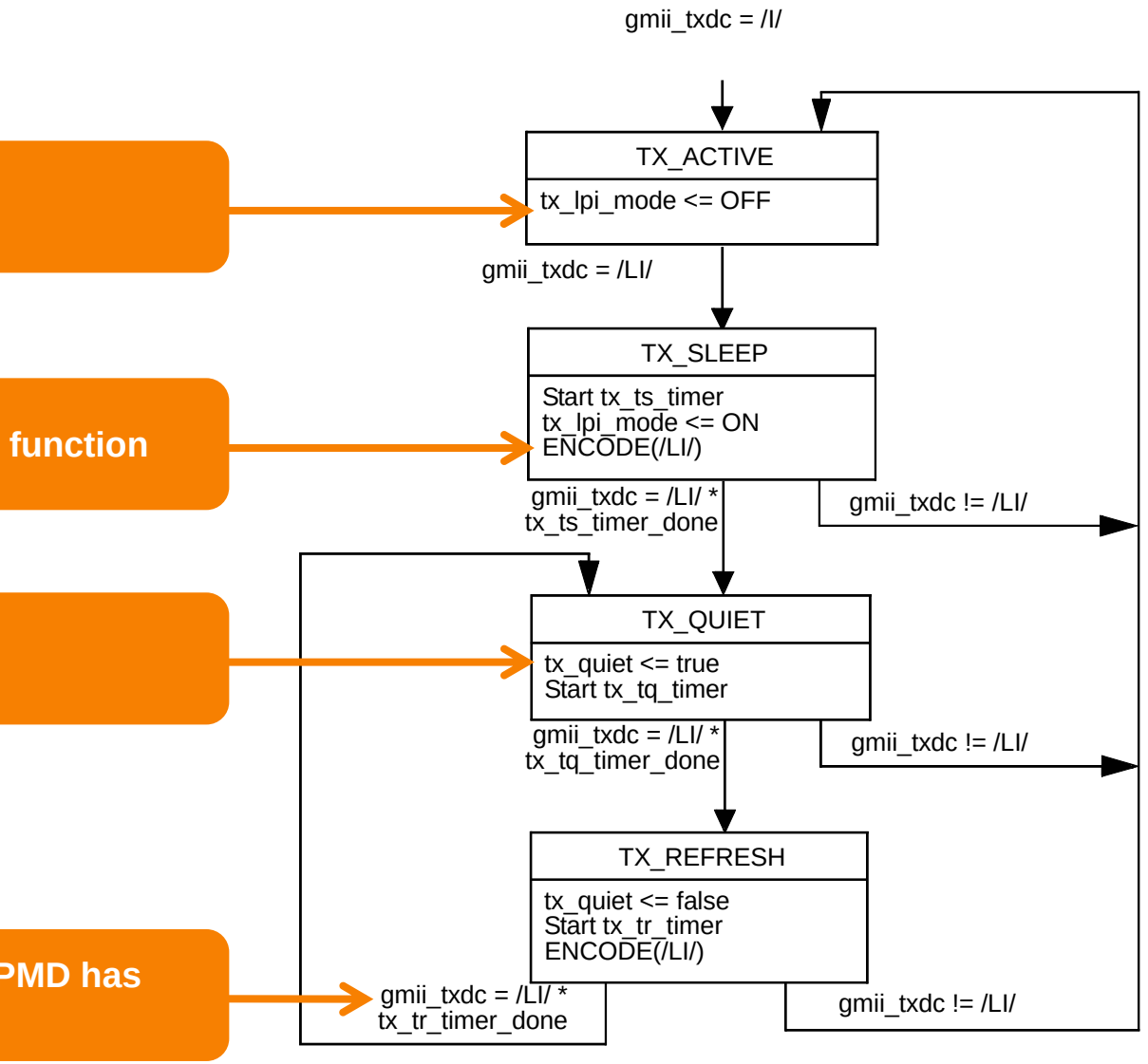
- PCS encoding and decoding of low-power idle is not completely defined in Clause 36
- Clause 70 state diagrams incorporate a mixture of PCS and PMD functions violating the layering model
- Clause 70 state diagrams define variables and timers that have no obvious use
- Clause 70 transmit disable and signal detect requirements are not adequate to ensure reliable transitions to quiet or wake

Who uses tx_lpi_mode?

ENCODE is really a PCS-level function

Who uses tx_quiet?

gmii_txdc presumes that the PMD has access to the GMII

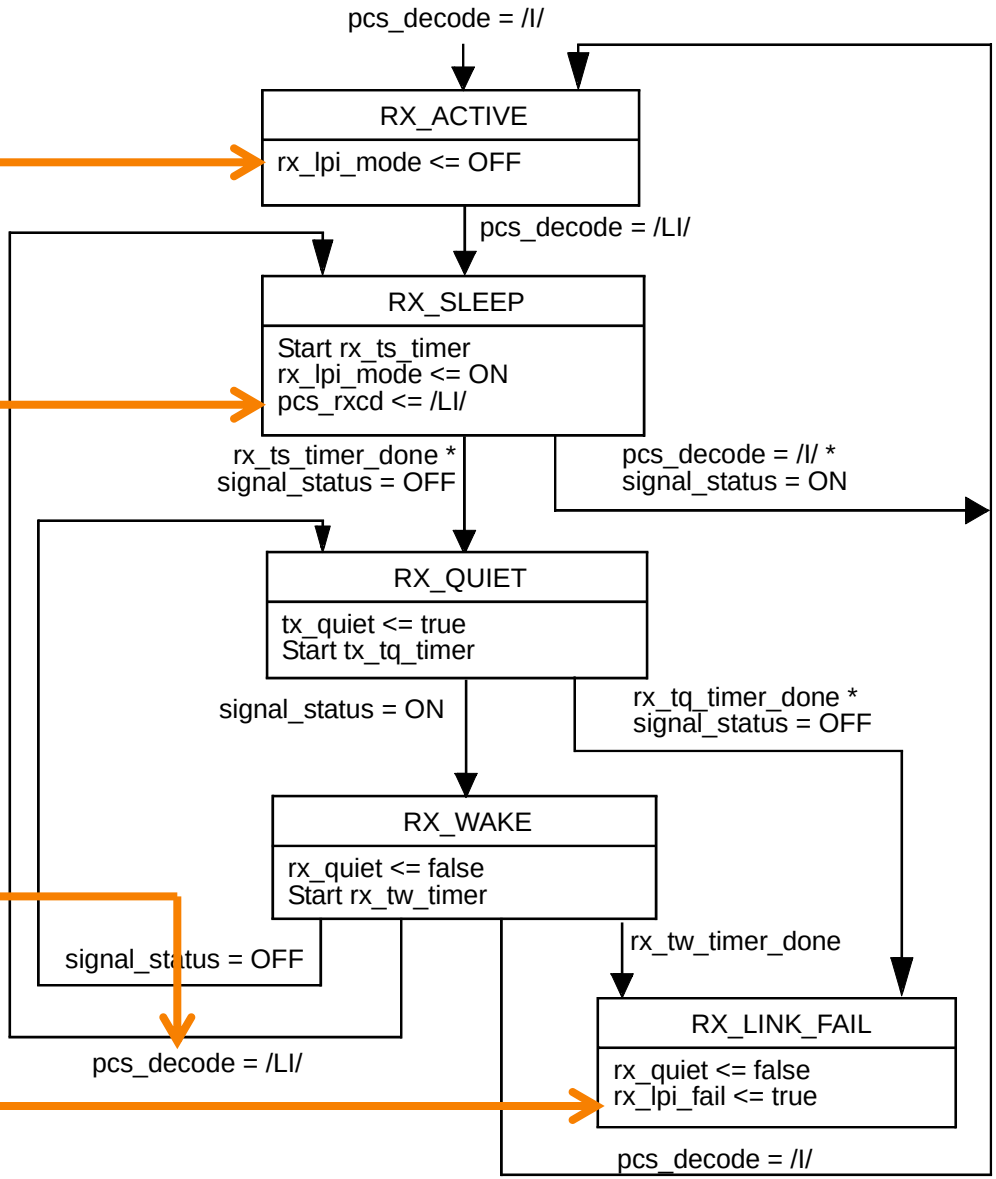


Who uses rx_lpi_mode?

pcs_rxcd presumes the PMD has access to the GMII?

How does the PMD know the result of this PCS-level function?

Who uses rx_quiet or rx_lpi_fail?



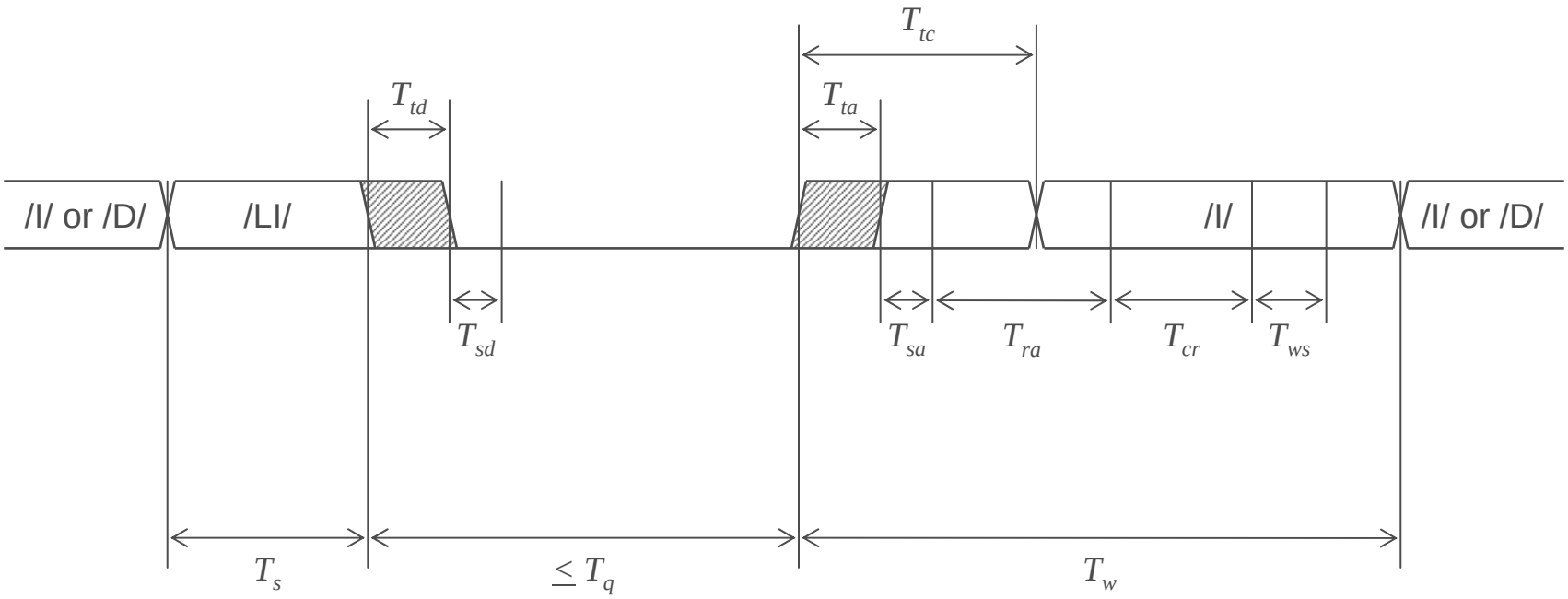
So, what do we do?

- Define only PMD specific functions in Clause 70
  - Transmitter de-activation and re-activation behavior
  - Transmitter quiet-refresh cycle timing
  - Signal detect assertion and de-assertion behavior

- Rigorously define the low-power idle encoding and decoding process in Clause 36
  - Also, may want to take measures to prevent sync_status cycling between OK and FAIL during quiet-refresh cycles
  - May want to include a watchdog timer to distinguish between quiet-refresh cycles and loss of link

- Define new service interface primitives to support any required inter-sublayer communication

Timing diagram: Sleep to wake



Legend			
T_s	Sleep time	T_{sd}	Receiver signal_detect de-assertion time
T_q	Quiet time	T_{sa}	Receiver signal_detect assertion time
T_w	Wake time	T_{ra}	Receiver activation time
T_{td}	Transmitter de-activation time	T_{cr}	Receiver timing acquisition time
T_{ta}	Transmitter activation time	T_{ws}	Receiver PCS synchronization time

Framework review

- Assume that transmit and receive functions are deactivated during the quiet periods to conserve energy
  - With the exception of the signal detect function

- The transmit functions will take some time to achieve normal operation following activation
  - Let T_{ta} be the time it takes for the transmitter to deliver a signal capable of triggering the receiver's signal detect function
  - Let T_{tc} be the time it take the transmitter to achieve compliant operation

- If, during the quiet period, the signal detect function is triggered, then receiver functions are reactivated
  - Let T_{sa} be the signal detection assertion time. assuming the transmitter is delivering a suitable signal
  - Let $T_{ra} + T_{cr}$ be the time it takes the receiver to return to normal operation and recover timing from the incoming signal, assuming the transmitter is delivering a compliant signal

Criteria for reliable transition to quiet

- The transmitter differential output voltage required to de-assert signal detect (V_{tq}) must be defined
  - This voltage should be greater than the peak noise voltage expected at the receiver
  - This voltage is the lower bound of the signal detect de-assertion threshold, V_{sd}
  - The reference time for the measurement of transitions from sleep to quiet is the point where the peak differential output voltage crosses V_{tq}
  - Similarly, the measurement of transitions from quiet to refresh or wake is the point where the where the peak differential output voltage crosses V_{tw}

Criteria for reliable wake

$$T_w \geq \max(T_{ta}^{\max} + T_{sa}^{\max} + T_{ra}^{\max}, T_{tc}^{\max}) + T_{cr}^{\max} + T_{ws}^{\max}$$

- Wake time cannot be guaranteed because essential parameters T_{ta} and T_{tc} are not constrained
- Transmitter differential output voltage required to trigger signal detect (V_{tw}), at the output of a worst-case channel, must be defined
  - This voltage must be delivered no later than T_{ta} following activation of the transmitter
  - The voltage at the output of the channel is established as the signal detect assertion threshold, V_{tw}
  - It must also be larger than the peak noise voltage expected at the receiver
- It is likely that T_{sa}, T_{ra}, T_{cr}, and T_{ws} may not be measured individually, but values should be established for the purpose of budgeting

Recommendations

- Use the proposed framework as the basis for updates to Clause 36 and Clause 70
- Similar issues exit with 10GBASE-KX4 and 10GBASE-KR
- Review Clauses 48, 49, 71, and 72 in light of these observations

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Questions?