Timing parameters for Energy Efficient Ethernet Backplane

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Comment #124: $T_{WR}$ for 10GBASE-KR

- The values for $T_{WR}$ in Table 49–3 are too large
  - They significantly exceed the minimum permissible value of $T_{w\_sys\_tx}$ per Table 78–4
  - Packet(s) transmitted immediately following the minimum deferral time, but before $rx\_tw\_timer\_done$, will be lost and no wake error will be recorded to account for their absence

- The rationale for the current $T_{WR}$ values may be found in comment #130 submitted against Draft 2.1
  - If the PHY wakes while in the TX_REFRESH state, scrambler bypass will be delayed
  - The receiver requires scrambler bypass to obtain block lock when the FEC sublayer is used
  - However, there was no need to increase $T_{WR}$ when the FEC sublayer is not used
Comment #124: Suggested remedy

• Modify the LPI transmit state diagram
  – Define refresh to be TX_ALERT and TX_WAKE immediately followed by TX_SLEEP
  – If scr_bypass_enable = TRUE, unconditionally enter TX_SCR_BYPASS when rx_tw_timer_done
  – From TX_SCR_BYPASS, move to TX_SLEEP (refresh) or TX_ACTIVE (wake) when one_us_timer_done

• Greatly simplifies state diagram structure

• PHY power-up sequence is identical for refresh, wake, and wake from refresh

• $T_{WR}$ can be set to a value that accurately accounts for wake errors
Figure 49-16—LPI Transmit state diagram
Timing diagram: SLEEP to REFRESH

SLEEP to REFRESH (\texttt{scr\_bypass\_enable} = \texttt{FALSE}): 

\begin{itemize}
  \item TX XGMII: Normal inter-frame
  \item TX PCS: \texttt{TX\_ACTIVE} \rightarrow \texttt{TX\_SLEEP} \rightarrow \texttt{TX\_QUIET} \rightarrow \texttt{TX\_WAKE} \rightarrow \texttt{TX\_SLEEP} \rightarrow \texttt{TX\_QUIET}
  \item \texttt{TX\_ALERT}
  \item \texttt{TX\_SCR\_BYPASS}
\end{itemize}

\begin{itemize}
  \item \texttt{T\_SL} \rightarrow \texttt{T\_QL} \rightarrow \texttt{T\_WL} \rightarrow \texttt{T\_SL}
  \item \texttt{T\_s} \rightarrow \texttt{T\_q} \rightarrow \texttt{T\_r}
\end{itemize}

SLEEP to REFRESH (\texttt{scr\_bypass\_enable} = \texttt{TRUE}): 

\begin{itemize}
  \item TX XGMII: Normal inter-frame
  \item TX PCS: \texttt{TX\_ACTIVE} \rightarrow \texttt{TX\_SLEEP} \rightarrow \texttt{TX\_QUIET} \rightarrow \texttt{TX\_WAKE} \rightarrow \texttt{TX\_SLEEP} \rightarrow \texttt{TX\_QUIET}
  \item \texttt{TX\_ALERT} \rightarrow \texttt{TX\_SCR\_BYPASS}
  \item \texttt{TX\_ALERT}
\end{itemize}

\begin{itemize}
  \item \texttt{T\_SL} \rightarrow \texttt{T\_QL} \rightarrow \texttt{T\_WL} \rightarrow \texttt{T\_SL}
  \item \texttt{T\_s} \rightarrow \texttt{T\_q} \rightarrow \texttt{T\_r}
\end{itemize}

(\texttt{scr\_bypass\_enable} = \texttt{FALSE})

(\texttt{scr\_bypass\_enable} = \texttt{TRUE})
Timing diagram: WAKE from REFRESH

WAKE from REFRESH (scr_bypass_enable = FALSE):

Normal inter-frame Assert LPI Normal inter-frame

TX XGMII

TX PCS

TX_ACTIVE TX_SLEEP TX QUIET TX_WAKE TX_ACTIVE

T_SL T_QL T_WL T_{1U}

TX ALERT

WAKE from REFRESH (scr_bypass_enable = TRUE):

Normal inter-frame Assert LPI Normal inter-frame

TX XGMII

TX PCS

TX_ACTIVE TX_SLEEP TX QUIET TX_WAKE TX_ACTIVE

T_SL T_QL T_WL T_{1U} T_{1U}

TX ALERT TX_SCR_BYPASS
Timing diagram: WAKE from QUIET, no FEC

WAKE from QUIET (scr_bypass_enable = FALSE):

TX XGMII
Assert LPI
Normal inter-frame
Data

TX PCS
TX_ALERT
TX.Quit
TX.Wake
TX.Active

RX PCS
RX.Quit
RX.Wake
RX.Active

RX XGMII
Assert LPI
Normal inter-frame

T_{WR} (max.) = T_{WL} (min.) + T_{1U} (min.) - T_{TA} (max.) - T_{SA} (max.)
Timing diagram: WAKE from QUIET, with FEC

WAKE from QUIET (scr_bypass_enable = TRUE):

\[ T_{WR} (max.) = T_{WL} (min.) + 3 \times T_{1U} (min.) - T_{TA} (max.) - T_{SA} (max.) \]
Timing parameters

• Comment #124: Update $T_{WR}$ in Table 49-3
  – Proposed changes to the LPI state diagram also require modification of the $T_r$ range in Table 78–2

• Timer tolerances
  – Comment #138: Table 78–2 implies a 10% tolerance but Table 48–9 and 49–2 define a 1% tolerance and Table 36–3a does not define a tolerance
  – Comment #121: one_us_timer has no defined tolerance
  – Comment #111 (R. Horner): Define one_us_timer to be exactly five FEC blocks
  – Comments #178 and #191 (M. Brown): $T_{SL}$ and $T_{UL}$ tolerances are too tight

• Comments #134, 300, 302: Define the time the transmitter is allowed to achieve full compliance following wake
More nit-picking on timing

• Table 78–4 needs to be updated
  – Table 78–2 added a row for XGXS (XAUI) so shouldn’t Table 78–4 add one as well (even though neither are PHYs as suggested by the table caption)
  – Re-order the rows in some logical fashion
  – $T_{\text{phy\_shrink\_tx}}$ and $T_{\text{phy\_shrink\_rx}}$ should be “max” values

• Suggested remedy
  – The following tables attempt to address all of these considerations
As a matter of convention, transmitter wake time shrinkage will be referred to the point where the transmitter delivers a compliant signal ($T_{QD} + T_{TC}$).

Assume $T_{QD} (\text{max}) = T_{\text{phy\_prop\_tx}} (\text{min})$.
# Proposal for Clause 36

## Table 36-3a — Transmitter LPI timing parameters (proposed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{SL}$</td>
<td>Local Sleep Time from entering TX_SLEEP to transmit disable</td>
<td>20.0</td>
<td>21.0</td>
<td>μs</td>
</tr>
<tr>
<td>$T_{QL}$</td>
<td>Local Quiet Time from Transmitter disabled to start of TX_REFRESH state</td>
<td>2.5</td>
<td>2.6</td>
<td>ms</td>
</tr>
<tr>
<td>$T_{UL}$</td>
<td>Local Refresh Time from transmitter activated to the TX_QUIET state</td>
<td>20.0</td>
<td>21.0</td>
<td>μs</td>
</tr>
</tbody>
</table>

## Table 36-3b — Receiver LPI timing parameters (proposed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{QR}$</td>
<td>The time the receiver waits for signal detect while in the RX_SLEEP and RX_QUIET states before asserting rx_fault</td>
<td>3</td>
<td>4</td>
<td>ms</td>
</tr>
<tr>
<td>$T_{SR}$</td>
<td>The time the receiver waits while in the LP_IDLE_D state</td>
<td>22</td>
<td>24</td>
<td>μs</td>
</tr>
<tr>
<td>$T_{WR}$</td>
<td>Time to wake remote link partner’s receiver</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>$T_{WTF}$</td>
<td>Wake time fault recovery time</td>
<td></td>
<td>1</td>
<td>ms</td>
</tr>
</tbody>
</table>
Proposal for Clause 48

Table 48-9 — Transmitter LPI timing parameters (proposed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{SL}</td>
<td>Local Sleep Time from entering TX_SLEEP to transmit disable</td>
<td>20.0</td>
<td>21.0</td>
<td>µs</td>
</tr>
<tr>
<td>T_{QL}</td>
<td>Local Quiet Time from Transmitter disabled to start of TX_REFRESH state</td>
<td>2.5</td>
<td>2.6</td>
<td>ms</td>
</tr>
<tr>
<td>T_{UL}</td>
<td>Local Refresh Time from signal enable to signal disable</td>
<td>20.0</td>
<td>21.0</td>
<td>µs</td>
</tr>
</tbody>
</table>

Table 48-10 — Receiver LPI timing parameters (proposed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{QR}</td>
<td>The time the receiver waits for signal detect while in the RX_SLEEP and RX_QUIET states before asserting rx_fault</td>
<td>3</td>
<td>4</td>
<td>ms</td>
</tr>
<tr>
<td>T_{WR}</td>
<td>Time to wake remote link partner's receiver</td>
<td>9</td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td>T_{WTF}</td>
<td>Wake time fault recovery time</td>
<td>1</td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>
### Proposal for Clause 49

#### Table 49-2 — Transmitter LPI timing parameters (proposed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{SL}$</td>
<td>Local Sleep Time from entering TX_SLEEP to transmit disable</td>
<td>5.0</td>
<td>6.0</td>
<td>μs</td>
</tr>
<tr>
<td>$T_{QL}$</td>
<td>Local Quiet Time from Transmitter disabled to start of TX_REFRESH state</td>
<td>1.7</td>
<td>1.8</td>
<td>ms</td>
</tr>
<tr>
<td>$T_{WL}$</td>
<td>Local Wake Time from LPI de-asserted to TX_ACTIVE state</td>
<td>11.0</td>
<td>12.0</td>
<td>μs</td>
</tr>
<tr>
<td>$T_{1U}$</td>
<td>Time spent in the TX_ALERT and TX_SCR_BYPASS states</td>
<td>1.1</td>
<td>1.6</td>
<td>μs</td>
</tr>
</tbody>
</table>

#### Table 49-3 — Receiver LPI timing parameters (proposed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{QR}$</td>
<td>The time the receiver waits for signal detect while in the RX_SLEEP and RXQUIET states before asserting rx_fault</td>
<td>2</td>
<td>3</td>
<td>ms</td>
</tr>
<tr>
<td>$T_{WR}$</td>
<td>Time to wake remote link partner's receiver (when scr_bypass_enable = FALSE)</td>
<td>11.6</td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>$T_{WR}$</td>
<td>Time to wake remote link partner's receiver (when scr_bypass_enable = TRUE)</td>
<td>13.8</td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>$T_{WTF}$</td>
<td>Wake time fault recovery time</td>
<td></td>
<td>1</td>
<td>ms</td>
</tr>
</tbody>
</table>
## Proposal for Clause 78 (insert rows in speed order)

### Table 78-2 — Summary of the key EEE parameters for supported PHYs (proposed)

<table>
<thead>
<tr>
<th>Protocol</th>
<th>$T_s$ µs</th>
<th>$T_q$ µs</th>
<th>$T_r$ µs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
</tr>
<tr>
<td>1000BASE-KX</td>
<td>20.0</td>
<td>21.0</td>
<td>2,500</td>
</tr>
<tr>
<td>XAUI</td>
<td>20.0</td>
<td>21.0</td>
<td>2,500</td>
</tr>
<tr>
<td>10GBASE-KX4</td>
<td>20.0</td>
<td>21.0</td>
<td>2,500</td>
</tr>
<tr>
<td>10GBASE-KR</td>
<td>5.0</td>
<td>6.0</td>
<td>1,700</td>
</tr>
</tbody>
</table>

### Table 78-4 — Summary of the LPI timing parameters for supported PHYs (proposed)

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Case</th>
<th>$T_{w_{sys_tx}}$ (min), in µs</th>
<th>$T_{w_{phy}}$ (min), in µs</th>
<th>$T_{phy_shrink_tx}$ (max), in µs</th>
<th>$T_{phy_shrink_rx}$ (max), in µs</th>
<th>$T_{w_{sys_rx}}$ (min), in µs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000BASE-KX</td>
<td>Case-1</td>
<td>13.26</td>
<td>11.25</td>
<td>5.0</td>
<td>6.5</td>
<td>1.76</td>
</tr>
<tr>
<td></td>
<td>Case-2</td>
<td>15.38</td>
<td>12.25</td>
<td>5.0</td>
<td>7.5</td>
<td>2.88</td>
</tr>
<tr>
<td>XAUI</td>
<td></td>
<td>12.38</td>
<td>9.25</td>
<td>5.0</td>
<td>4.5</td>
<td>2.88</td>
</tr>
<tr>
<td>10GBASE-KX4</td>
<td></td>
<td>12.38</td>
<td>9.25</td>
<td>5.0</td>
<td>4.5</td>
<td>2.88</td>
</tr>
<tr>
<td>10GBASE-KR</td>
<td>Case-1</td>
<td>15.38</td>
<td>12.25</td>
<td>5.0</td>
<td>7.5</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td>Case-2</td>
<td>17.38</td>
<td>14.25</td>
<td>5.0</td>
<td>9.5</td>
<td>2.88</td>
</tr>
</tbody>
</table>