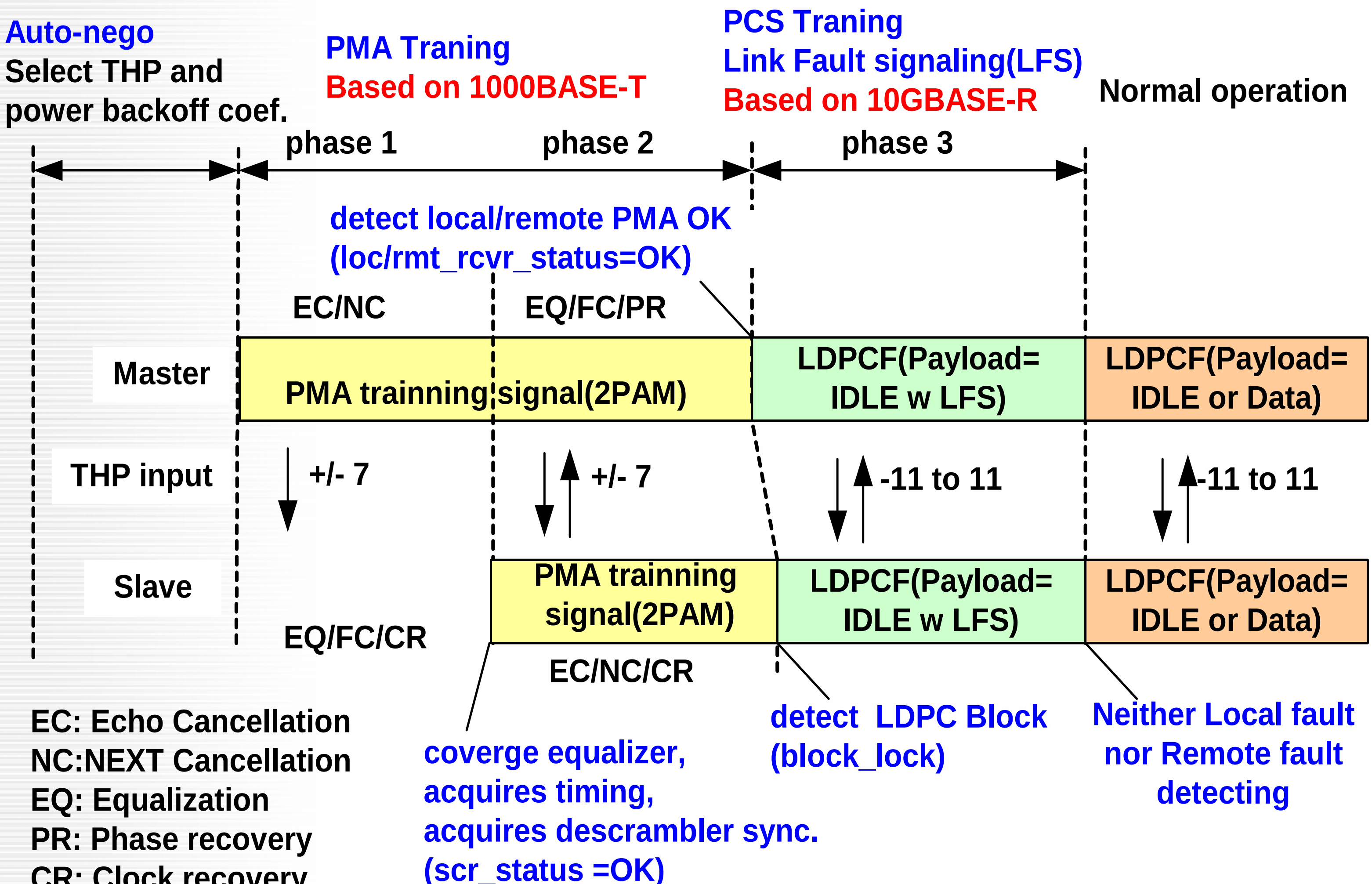
Startup protocol for 10GBASE-T

Nov. 2004

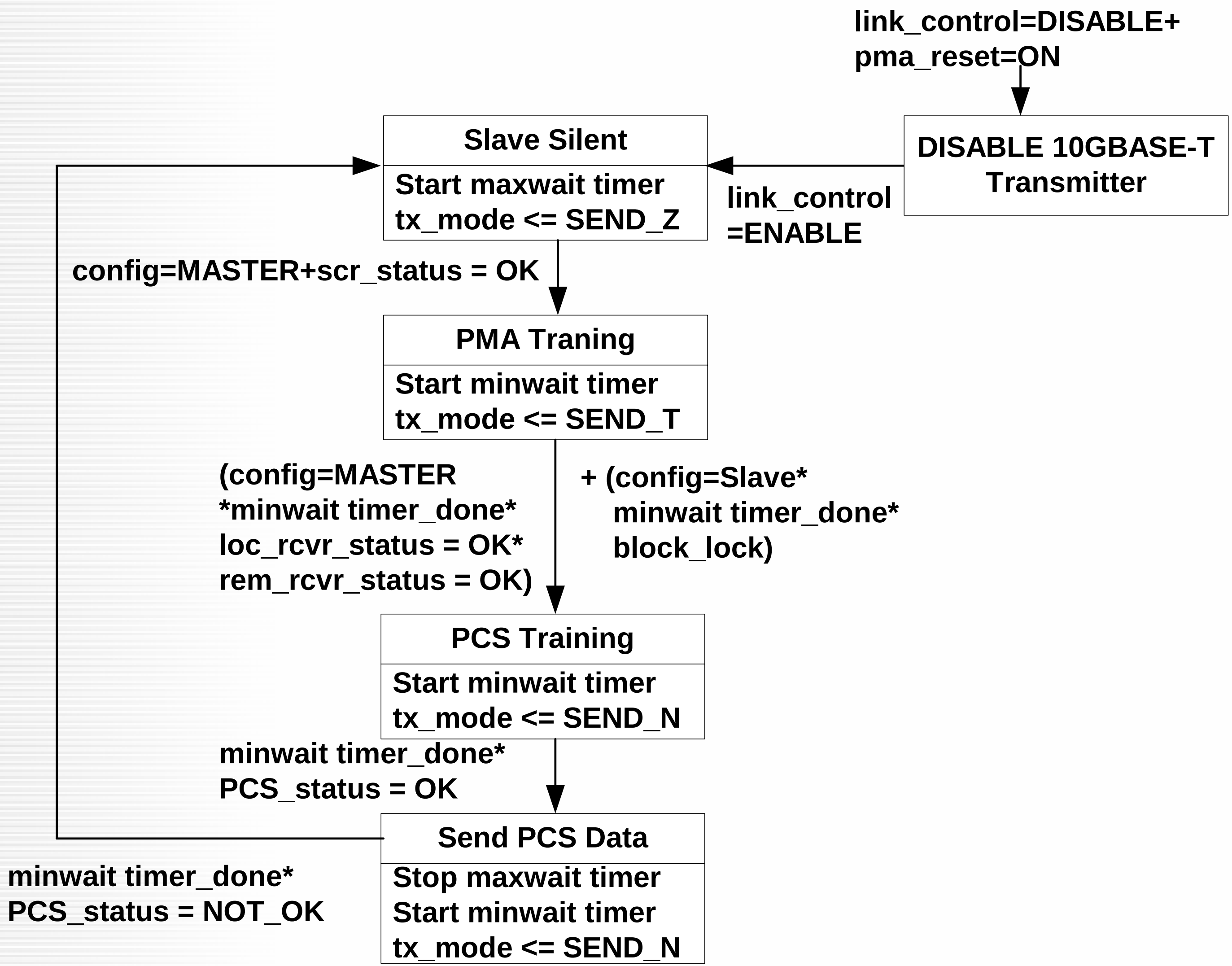
Katsutoshi SEKI, NEC Electronics

Overview

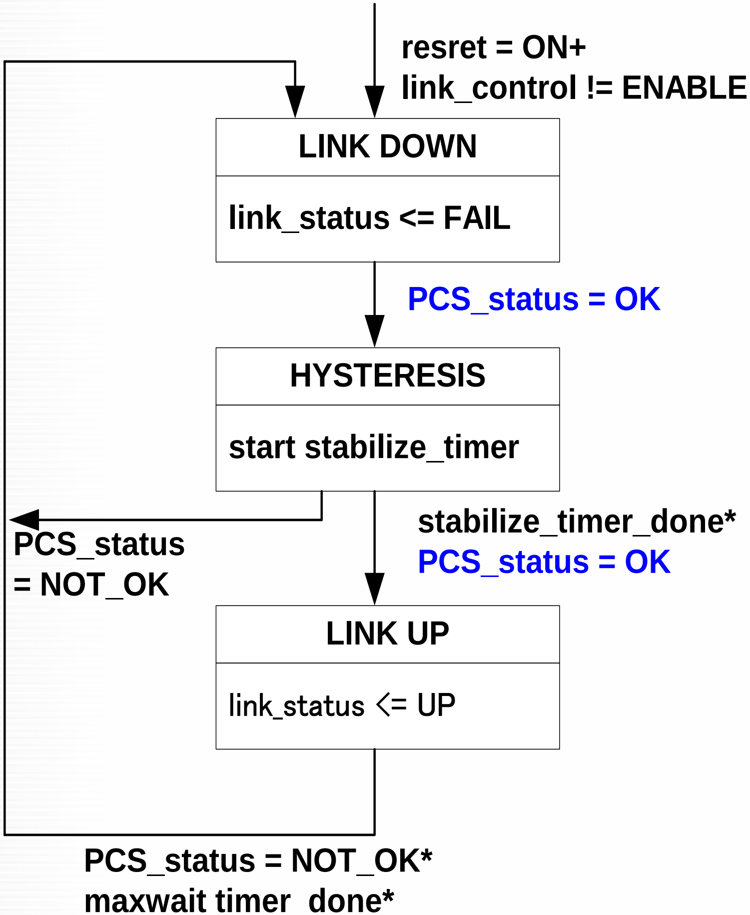


EC: Echo Cancellation
NC:NEXT Cancellation
EQ: Equalization
PR: Phase recovery
CR: Clock recovery
LDPCF : LDPC Frame

PHY Control State Diagram



Link Monitor State Diagram



The valiable link_status and link_control are designated as link_control_(10GigT) and link_status_(10GigT), respectively, by Auto-negotiation Arbitration state diagram (Fig28-16)

State diagram variables

Variables	Description
link_control	This variable is defined in 28.2.6.2.
link_status	This variable is defined in 28.2.6.1.
loc_rcvr_status	Variable set by the PMA Receive function to indicate correct or incorrect operation of the receive PMA link for the local PHY. Values: OK: The receive PMA link for the local PHY is operating reliably NOT_OK: Operation of the receive PMA link for the local PHY is unreliable
pma_reset	Allows reset of all PMA functions. Values: ON or OFF Set by: PMA Reset
rem_rcvr_status	Variable set by the PCS Receive function to indicate whether correct operation of the receive PMA link for the remote PHY is detected or not Values: OK: The receive PMA link for the remote PHY is operating reliably NOT_OK: Operation of the receive PMA link for the remote PHY is unreliable
scr_status	The scr_status parameter as communicated by the PMA_SCRSTATUS.request primitive Values: OK: The descrambler has achieved synchronization. NOT_OK: The descrambler is not synchronized
PCS_status	This variable is defied in 55.3.13.1
block_lock	This variable is defined in 55.3.13.1
tx_mode	PCS Transmit sends code-groups according to the value assumed by this variable. Values: SEND_N This value is continuously asserted when transmission of sequences of four dimensional symbols representing a XGMII data stream in normal mode. SEND_T This value is continuously asserted when transmission of PMA training signal. SEND_Z This value is continuously asserted when transmission of zeros.

Timers

Timer	Description
maxwait_timer	A timer used to limit the amount of time during which a receiver dwells in the SLAVE SILENT, PMA TRAINING and PCS Training states. The timer shall expire 750 ± 10 ms if config = MASTER or 350 ± 5 ms if config = SLAVE. This timer is used jointly in the PHY Control and Link Monitor state diagrams. The maxwait_timer is tested by the Link Monitor to force link_status to be set to FAIL if the timer expires and PCS_status is NOT_OK.
minwait_timer	A timer used to determine the minimum amount of time the PHY Control stays in the PMA TRAINING, PCS TRAINIG, and SEND PCS DATA states. The timer shall expire 1 ± 0.1μs after being started.
stabilize_timer	A timer used to control the minimum time that loc_rcvr_status must be OK before a transition to Link Up can occur. The timer shall expire 1 ± 0.1 μs after being started.

Expire times are re-used from 1000BASE-T.

1) **These expire times are closely related to auto-negotiation state diagram**
2) **These expire times are enough for PMA/PCS training.**

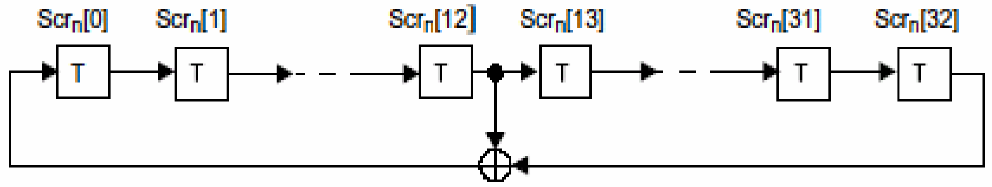
PMA Training signal

Objective:

- Recover timing and adaptive filter coefficients
- Establish polarity correction, pair swap, pair deskew

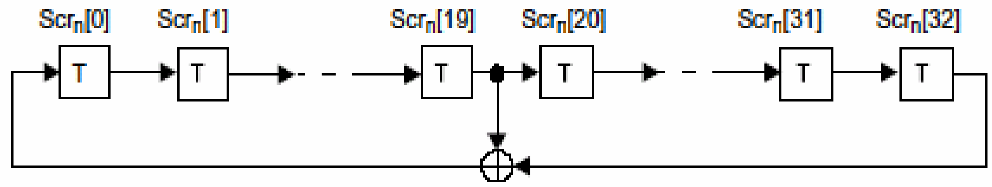
Side stream scrambler: (ref IEEE802.3 40.3.1.3.1)

Side-stream scrambler employed by the MASTER PHY



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

Side-stream scrambler employed by the SLAVE PHY



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

PMA Training signal (cont')

Generation of bits Syn[3:0]

$$Sy_n[0] = Scr_n[0]$$

$$Sy_n[1] = g(Sy_n[0]) = Scr_n[3] \wedge Scr_n[8]$$

$$Sy_n[2] = g(Sy_n[1]) = Scr_n[6] \wedge Scr_n[16]$$

$$Sy_n[3] = \begin{cases} g(Sy_n[2]) \wedge Sy_n[0] = Scr_n[9] \wedge Scr_n[14] \wedge Scr_n[19] \wedge Scr_n[24] \wedge Scr_n[0] & \textbf{if(loc\_rcvr\_status} = \textbf{NG)} \\ g(Sy_n[2]) \wedge Sy_n[1] = Scr_n[9] \wedge Scr_n[14] \wedge Scr_n[19] \wedge Scr_n[24] \wedge Scr_n[3] \wedge Scr_n[8] & \textbf{else} \end{cases}$$

$$g(x) = x^3 + x^8$$

Generation of Transmit symbol vector

$$A = \begin{cases} 7 \; if \; (Sy_n[0] = 0) \\ -7 \; else \end{cases} \qquad B = \begin{cases} 7 \; if \; (Sy_n[1] = 0) \\ -7 \; else \end{cases}$$

$$C = \begin{cases} 7 \; if \; (Sy_n[2] = 0) \\ -7 \; else \end{cases} \qquad D = \begin{cases} 7 \; if \; (Sy_n[3] = 0) \\ -7 \; else \end{cases}$$

PMA Training signal (cont')

Polarity correction

$$Ry_n[x] \wedge Ry_{n-13}[x] \wedge Ry_{n-33}[x] = \begin{cases} 0 \ \textbf{(polarity = OK)} \\ 1 \ \textbf{(polarity = NG)} \end{cases} (x = 0,1,2,3)$$

$Ry_n[x]$: **PAM2 demapping data of Lane x**

Pair swap, deskew

$$Ry_n[x] \wedge Ry_{n-3}[x-1] \wedge Ry_{n-8}[x-1] = \begin{cases} 0 \ \textbf{(skew = OK)} \\ 0/1 \ \textbf{(skew = NG)} \end{cases} (x = 1,2)$$

if (remote side PMA status = NG)

$$Ry_n[3] \wedge Ry_{n-3}[2] \wedge Ry_{n-8}[2] \wedge Ry_n[0] = \begin{cases} 0 \ \textbf{(skew = OK)} \\ 0/1 \ \textbf{(skew = NG)} \end{cases}$$

else

$$Ry_n[3] \wedge Ry_{n-3}[2] \wedge Ry_{n-8}[2] \wedge Ry_n[1] = \begin{cases} 0 \ \textbf{(skew = OK)} \\ 0/1 \ \textbf{(skew = NG)} \end{cases}$$

- There is only one pair combination which satisfy all equations become 0
- By using the relationship, PMA status of remote side receiver (rem_rcvr_status) can be detected

Proposal Summary

NEC

Startup sequence :

- **Select predetermined THP/Power backoff coefficients at auto-negotiation or cable diagnostics**

  TF needs further investigation about THP/Power backoff coef choosing method

- **PMA training based on 1000BASE-T**
- **PCS training and link fault signaling based on 10GBASE-R**

2PAM PMA Training signal :

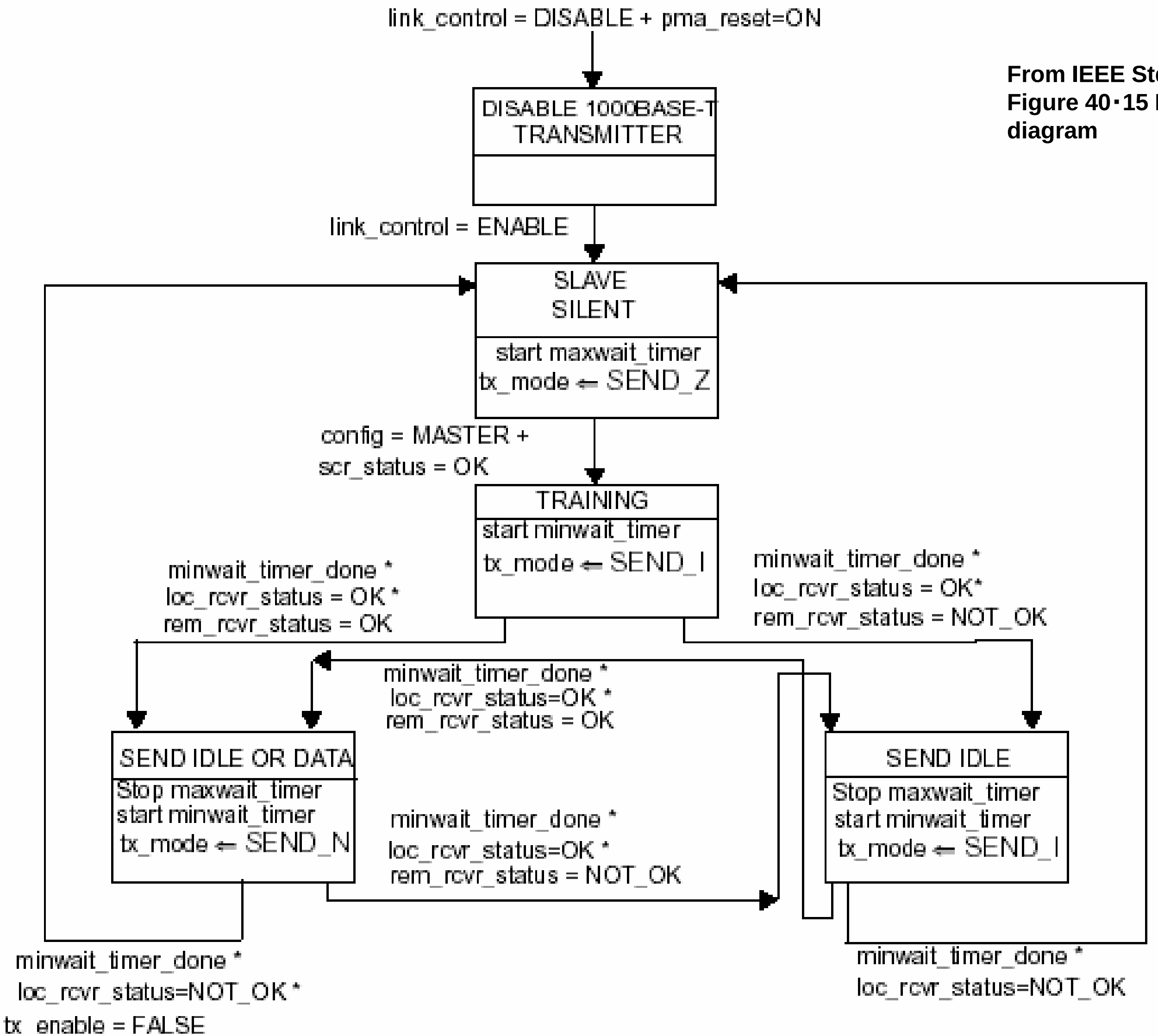
By using proposed PMA training signal, polarity correction, pair swap, pair deskew can be established

Backup

1000BASE-T PHY Control state diagram

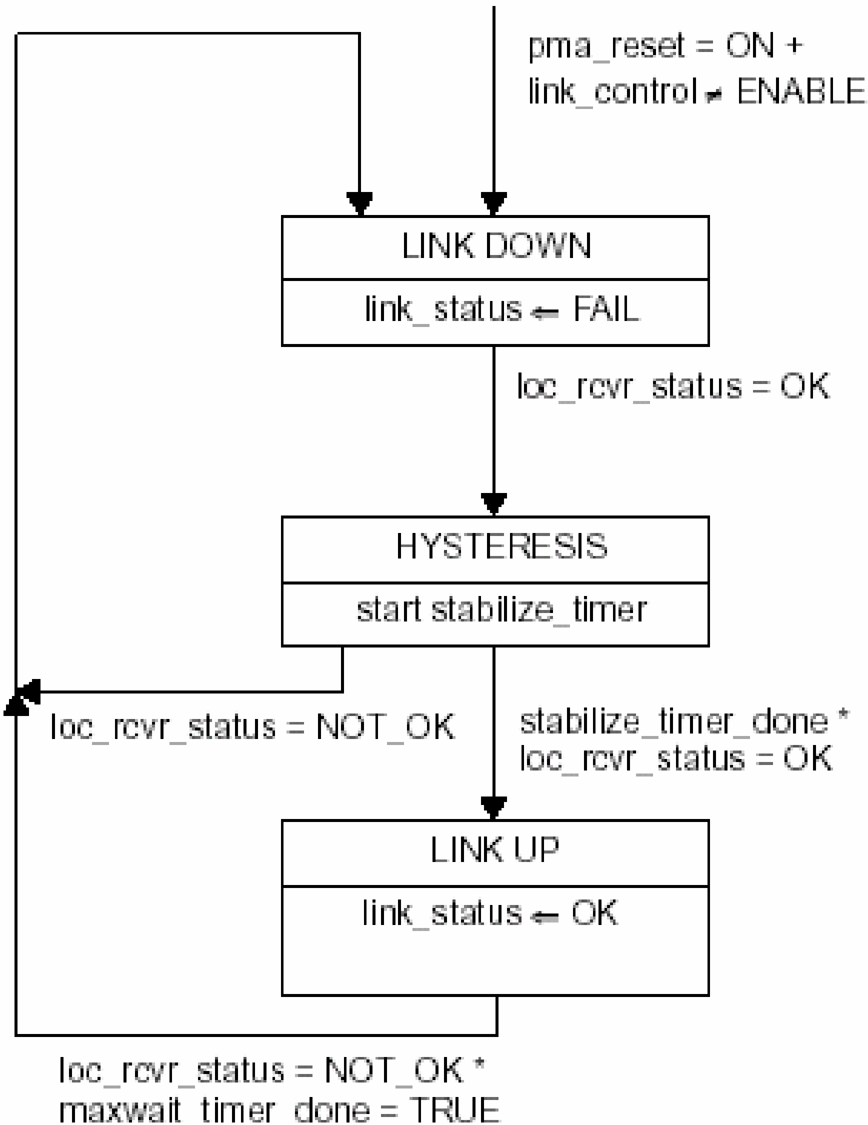
NEC

From IEEE Std 802.3-2002
Figure 40-15 PHY Control state diagram



1000BASE-T Link Monitor state diagram

NEC



From IEEE Std 802.3-2002
Figure 40‐16 link Monitor state diagram

1000BASE-T PMA training signal

- The number of levels : 3-level signal

  The 4 scrambler sequences were used to generate 2-level sequences, but the 2 levels were (0,-2). An additional polarity scrambler randomly flipped the polarity of the -2 to get a 3-level signal.

- Mechanism to identify pair A.

  The 2-level sequences for pairs A, pair B,C & D was different.
  Pairs B,C & D alternate between odd and even times.
  At even time periods pair B,C,D are the same as the scrambler sequence.
  At odd time periods pair B,C,D are the inverse of the scrambler sequence from even time period.
  And then, an additional polarity scrambler randomly flipped the polarity.

Our proposal didn't apply 1000BASE-T approach

  1000BASE-T approach requires polarity scrambler.
  This bring us increasing complexity in polarity correction, deskew and pair swapping, because our proposal uses 2PAM training signal, not 3PAM.