

Mechanisms Influencing BASE-T 1Gb/10Gb Time-To-Link

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Purpose

- Identify some of the bigger and smaller levers associated with achieving a 1000BASE-T or 10GBASE-T link
- Follow-up to previous contributions characterizing time-to-link (TTL)
 - “Increase the magnification” on reported times
- Starting point for future discussions on improving TTL for 2.5G/5GBASE-T PHYs
 - “First, do no harm”

What is Time-To-Link (TTL)?

- Time-To-Link (TTL): A system performance metric that characterizes and measures PHY behavior through autonegotiation and 1G/10G BASE-T startup sequences

- Autonegotiation in 802.3 Clause 28, “Physical Layer link signaling for Auto-Negotiation on twisted pair”
- 1Gb in 802.3 Clause 40, Subclause 40.4.2.4, “PHY Control function”
- 10Gb in 802.3 Clause 55, Subclause 55.4.2.5.14, “Startup sequence”

- One of two primary performance measures (along with BER) used to characterize BASE-T physical layer link interoperability

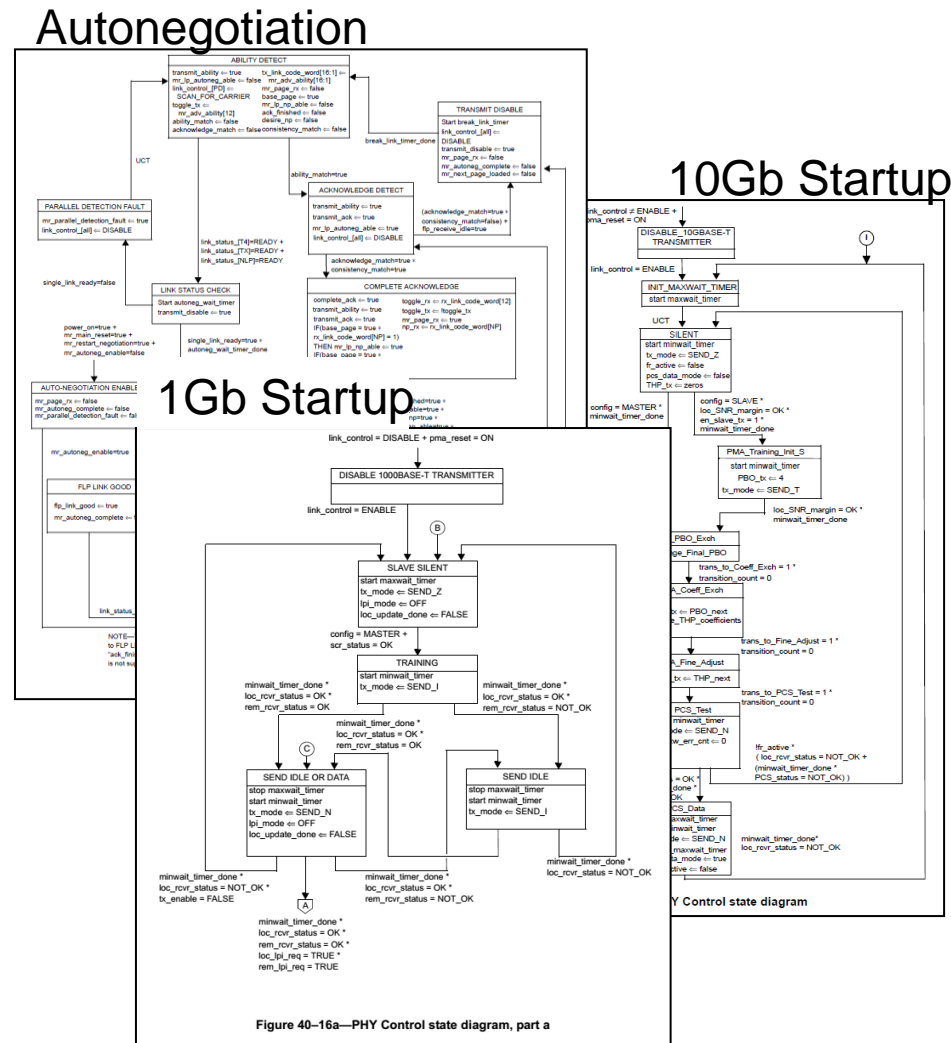


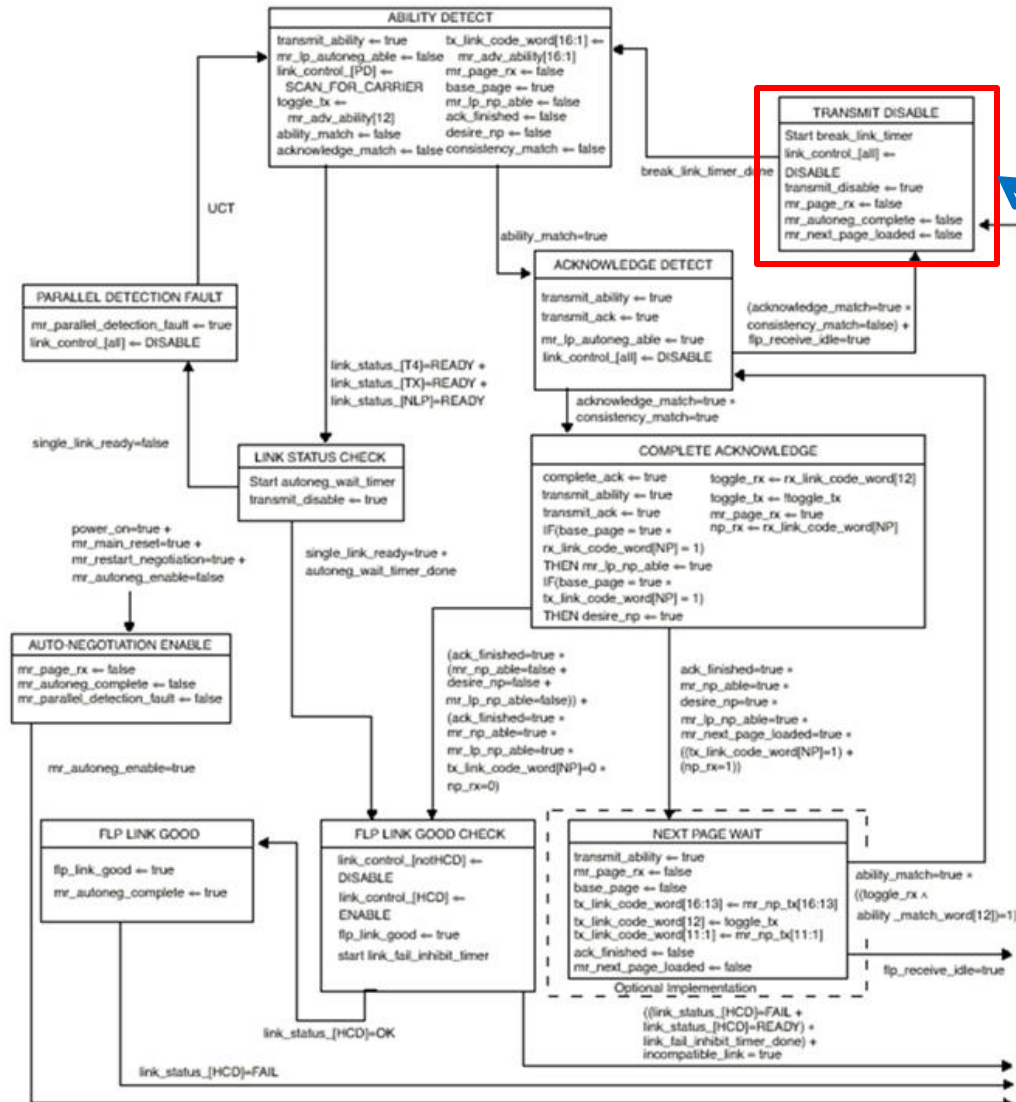
Figure 40-16—PHY Control state diagram, part a

Typical startup flow

- Initiate a link event (PHY reset, AN restart, or pulling a cable)
- In some cases, wait for the break_link_timer to expire
- Begin and complete autonegotiation
- Begin and complete PHY startup

It's easy, right?

Autonegotiation Arbitration State Diagram



Breaking a link usually gets us to this state as a starting point

Representative 1Gb link

- 10GBASE-T PHY to 1000BASE-T partner
- Initiate link event & wait for timer to expire
- Exchange base page and any required next pages
- When autonegotiation is complete, begin the startup & training process
- Establish (and maintain) link

Break Link and PHY link check	
autoneg arbitration state = 0	
autoneg arbitration state = 1	
autoneg arbitration state = 2	
Copper not connected	0:00:01.796
autoneg arbitration state = 2	
autoneg arbitration state = 3	
autoneg arbitration state = 2	
autoneg arbitration state = 3	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 6	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 6	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 6	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 7	
ANEG in Gphy mode	
autoneg arbitration state = 8	
ANEG Completed: #4	0:00:02.734
1Gb Training	0:00:01.000
Link_#4_iteration_#1 - Link Up	0:00:05.655

Representative 10Gb link

- 10GBASE-T PHY to peer 10Gb partner
- Initiate link event & wait for timer to expire
- Exchange base page and any required next pages
- When autonegotiation is complete, begin the startup & training process
- Establish (and maintain) link

Break Link and PHY link check	
autoneg arbitration state = 0	
autoneg arbitration state = 1	
autoneg arbitration state = 2	
Copper not connected	0:00:01.594
autoneg arbitration state = 3	
autoneg arbitration state = 2	
autoneg arbitration state = 3	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 6	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 6	
autoneg arbitration state = 4	
ANG: LP Info (Same)	
autoneg arbitration state = 5	
autoneg arbitration state = 6	
autoneg arbitration state = 4	
autoneg arbitration state = 5	
autoneg arbitration state = 7	
lpXnp	
autoneg arbitration state = 8	
ANEG Completed: #5	0:00:00.437
10Gb Training	0:00:02.969
Link_#5_iteration_#1 - Link Up	0:00:05.000

A few 10GBASE-T links for comparison

10Gb #1
Peer PHY

1Gb #1
1Gb PHY

1Gb #2
1Gb PHY

10Gb #2
Peer PHY

1G #3
1Gb PHY

10G #3
Different PHY

State	Time	State	Time	State	Time	State	Time	State	Time	State	Time
										Break Link and PHY link check	
				Break Link and PHY link check		Break Link and PHY link check		Break Link and PHY link check		autoneg arbitration state = 0	
				autoneg arbitration state = 0		autoneg arbitration state = 0		autoneg arbitration state = 0		autoneg arbitration state = 1	
				autoneg arbitration state = 1		autoneg arbitration state = 1		autoneg arbitration state = 1		autoneg arbitration state = 2	
				autoneg arbitration state = 2		autoneg arbitration state = 2		autoneg arbitration state = 2		Copper not connected	0:00:02.390
		Break Link and PHY link check		autoneg arbitration state = 2		autoneg arbitration state = 2		autoneg arbitration state = 2		autoneg arbitration state = 3	
		autoneg arbitration state = 0		autoneg arbitration state = 3		Copper not connected	0:00:01.796	Copper not connected	0:00:01.594	autoneg arbitration state = 4	
		autoneg arbitration state = 1		autoneg arbitration state = 2		autoneg arbitration state = 3		autoneg arbitration state = 3		autoneg arbitration state = 4	
		autoneg arbitration state = 2		autoneg arbitration state = 3		autoneg arbitration state = 2		autoneg arbitration state = 2		autoneg arbitration state = 5	
autoneg arbitration state = 3		Copper not connected	0:00:02.234	autoneg arbitration state = 2		autoneg arbitration state = 3		autoneg arbitration state = 3		autoneg arbitration state = 6	
autoneg arbitration state = 4		autoneg arbitration state = 3		autoneg arbitration state = 3		autoneg arbitration state = 4		autoneg arbitration state = 4		autoneg arbitration state = 4	
autoneg arbitration state = 5		autoneg arbitration state = 4		autoneg arbitration state = 4		autoneg arbitration state = 5		autoneg arbitration state = 4		autoneg arbitration state = 5	
autoneg arbitration state = 6		autoneg arbitration state = 5		autoneg arbitration state = 5		autoneg arbitration state = 6		autoneg arbitration state = 5		autoneg arbitration state = 6	
autoneg arbitration state = 4		autoneg arbitration state = 6		autoneg arbitration state = 6		autoneg arbitration state = 4		autoneg arbitration state = 6		autoneg arbitration state = 4	
autoneg arbitration state = 5		autoneg arbitration state = 5		autoneg arbitration state = 4		autoneg arbitration state = 5		autoneg arbitration state = 4		autoneg arbitration state = 5	
autoneg arbitration state = 6		autoneg arbitration state = 4		autoneg arbitration state = 5		autoneg arbitration state = 6		autoneg arbitration state = 5		autoneg arbitration state = 6	
autoneg arbitration state = 4		autoneg arbitration state = 5		autoneg arbitration state = 6		autoneg arbitration state = 4		autoneg arbitration state = 6		autoneg arbitration state = 4	
ANEG in Gphy mode		autoneg arbitration state = 6		autoneg arbitration state = 4		ANEG in Gphy mode		autoneg arbitration state = 4		autoneg arbitration state = 4	
autoneg arbitration state = 5		autoneg arbitration state = 6		autoneg arbitration state = 5		autoneg arbitration state = 5		autoneg arbitration state = 5		autoneg arbitration state = 5	
autoneg arbitration state = 6		autoneg arbitration state = 5		autoneg arbitration state = 6		autoneg arbitration state = 6		autoneg arbitration state = 6		autoneg arbitration state = 6	
autoneg arbitration state = 4		autoneg arbitration state = 6		autoneg arbitration state = 4		autoneg arbitration state = 4		autoneg arbitration state = 4		autoneg arbitration state = 4	
autoneg arbitration state = 5		autoneg arbitration state = 4		autoneg arbitration state = 5		autoneg arbitration state = 5		autoneg arbitration state = 5		autoneg arbitration state = 5	
autoneg arbitration state = 7		autoneg arbitration state = 5		autoneg arbitration state = 6		autoneg arbitration state = 7		autoneg arbitration state = 6		autoneg arbitration state = 6	
lpXnp		autoneg arbitration state = 7		ANEG in Gphy mode		lpXnp		ANEG in Gphy mode		autoneg arbitration state = 7	
autoneg arbitration state = 8		ANEG in Gphy mode		autoneg arbitration state = 8		autoneg arbitration state = 8		autoneg arbitration state = 8		autoneg arbitration state = 8	
ANEG Completed: #1	0:00:00.469	ANEG Completed: #2	0:00:00.718	ANEG Completed: #4	0:00:02.734	ANEG Completed: #5	0:00:00.437	ANEG Completed: #6	0:00:00.734	ANEG Completed: #7	0:00:00.719
10Gb Training	0:00:02.000	1Gb Training	0:00:01.438	1Gb Training	0:00:01.000	10Gb Training	0:00:02.969	1Gb Training	0:00:01.438	10Gb Training	0:00:02.937
Link_#1_iteration_#1 - Link Up	0:00:02.469	Link_#2_iteration_#1 - Link Up	0:00:04.390	Link_#4_iteration_#1 - Link Up	0:00:05.655	Link_#5_iteration_#1 - Link Up	0:00:05.000	Link_#6_iteration_#1 - Link Up	0:00:04.610	Link_#7_iteration_#1 - Link Up	0:00:06.046

2m cable

55m cable

Time-To-Link* Summary

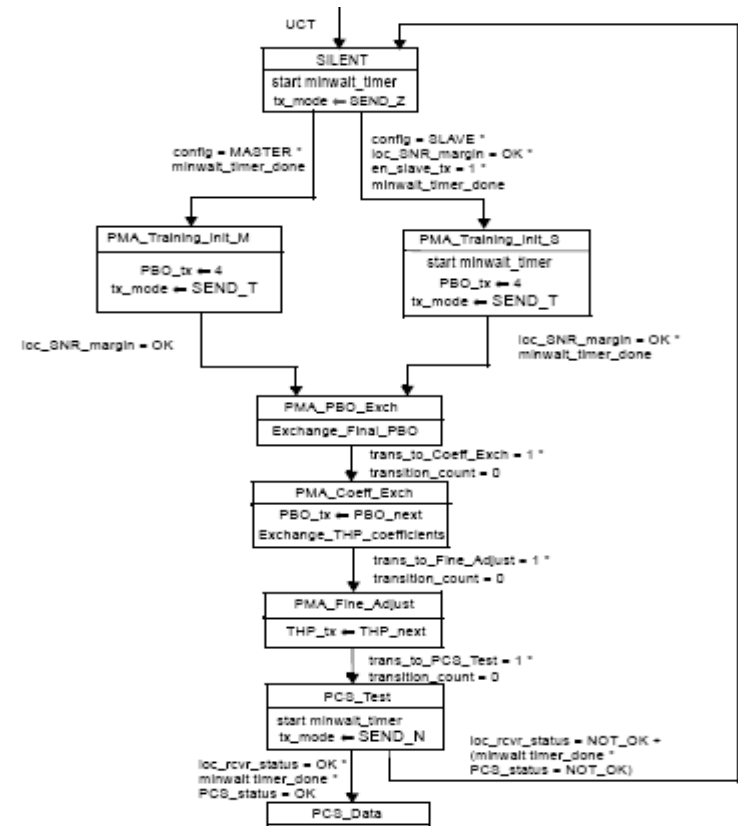
Speed	10Gb	1Gb	1Gb	10Gb	1Gb	10Gb
Cable	2m	2m	2m	55m	55m	55m
Partner	Peer	1Gb	1Gb	Peer	1Gb	Different
Break link time	n/a	02.234	01.796	01.594	02.438	02.390
Autonegotiation time	00.469	00.718	02.734	00.437	00.734	00.719
Startup & Training time	02.000	01.438	01.000	02.969	01.438	02.937
Total time	02.469	04.390	05.655	05.000	04.610	06.046
Break link %		50.89%	31.76%	31.88%	52.89%	39.53%
Autonegotiation %	19.00%	16.36%	48.35%	8.74%	15.92%	11.89%
Startup & Training %	81.00%	32.76%	17.68%	59.38%	31.19%	48.58%
	100.00%	100.00%	97.79%	100.00%	100.00%	100.00%

Some noticeable differences when linking to other PHYs

** As reported by the PHY – may not include time to reflect link status in autonegotiation or MAC registers*

10GBASE-T Training/Start-Up

- The original startup is described in 802.3an Subclause "55.4.2.5.14 Startup sequence"
 - Summary diagram is PHY Control, Fig 55-24 (shown at right). Master follows left path, Slave right
- Total allocated time is 2 sec. for the 6 total states
 - Only PCS_Test (last state) **has had** 1ms fixed time
 - Remaining 5 states **have had** no individual time budget assigned in standard – *each PHY may use this budget differently!*
- For most states, the exit criteria is controlled by mutual agreement with link partner – *both PHYs need to be in the same state to agree!*
- Time elapsed for most states is the max of the two ends of the link; *re-tries are allowed in the standard*



Updated 10Gb training and startup

The specification was updated to include recommended times for states before PCS_Test

Fast retrain support was also added



Table 55–9—Recommended startup sequence timing

Master	Recommended maximum time (ms)	Recommended average time (ms)	Slave
SILENT plus (PMA_Training_Init_M state AND en_slave_tx = 0)	350	315	SILENT
(PMA_Training_Init_M state AND en_slave_tx = 1) plus PMA_PBO_Exch state	480	432	PMA_Training_Init_S state plus PMA_PBO_Exch state
PMA_Coeff_Exch state	100	90	PMA_Coeff_Exch state with timing_lock_OK=0
	520	468	Total for PMA Coeff Exch state
PMA_Fine_Adjust state	650	585	PMA_Fine_Adjust state
Total	2000	1800	

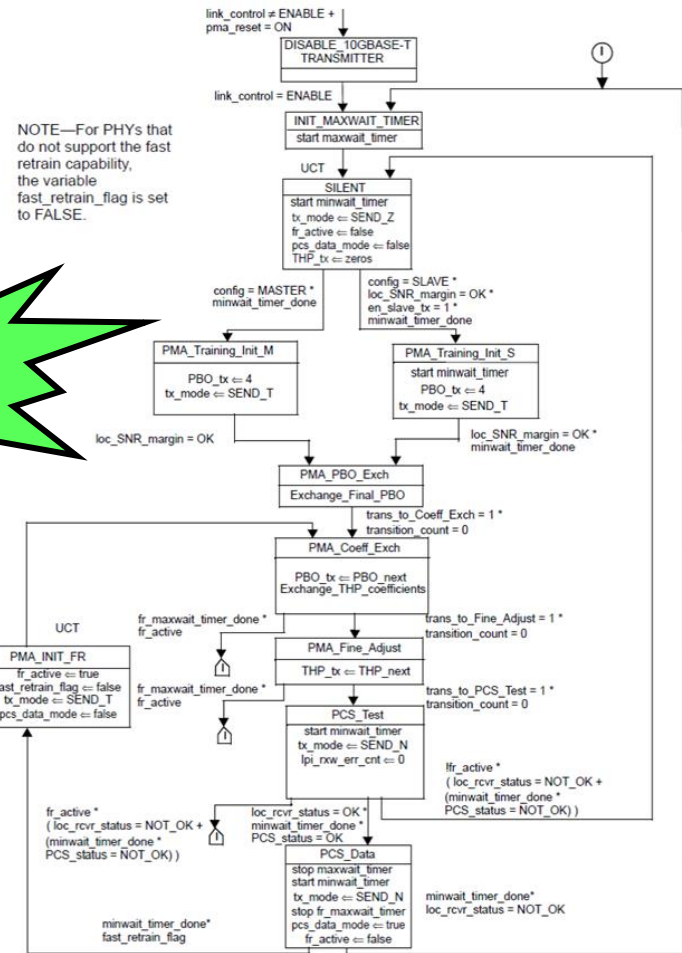


Figure 55–28—PHY Control state diagram

10Gb Startup Example

Time Stamp	State
0:00:00.000	Begin startup
0:00:00.000	ST: Remote signal detected
0:00:00.031	ST: Slave ready for PMA_TRAINING_INIT
0:00:00.344	Lane Map Complete
0:00:00.000	Begin PBO_EXCHANGE
0:00:00.000	Slave ready for PMA_PBO_EXCHANGE
0:00:00.156	FFE phase search done
0:00:00.000	Master ready for PMA_PBO_EXCHANGE
0:00:00.000	New PBO applied
0:00:00.094	Slave ready for PMA_COEFF_EXCH
0:00:00.016	Startup Start
0:00:00.140	SNR_delta: 0 and SNR_threshold: 0
0:00:00.000	Master ready for PMA_COEFF_EXCH
0:00:00.469	THP applied
0:00:00.031	THP applied
0:00:00.078	Loop A done
0:00:00.000	Loop B done
0:00:00.157	PMA_FINE_ADJUST done
0:00:00.437	Enter PCS_TEST (DSQ)
0:00:00.016	PCS_TEST done
0:00:00.015	Connect copper to XAUI
0:00:00.032	XAUI fully connected to copper
0:00:02.016	Startup complete

Summary

- Time-to-link from the end-user perspective
 - User time-to-link experience with the installed base of Cat5e/Cat6 cabling and 1000BASE-T is between 3s & 4s
 - User time-to-link experience with 10GBASE-T is ~6s to 7s (and in some cases, longer)
 - Measured 1000BASE-T and 10GBASE-T autonegotiation times are comparable
- Considerations for P802.3bz and the Architecture ad hoc
 - Can 2.5/5GBASE-T autonegotiation and startup times be improved to be more aligned with end-user expectations* and/or requirements?
 - *Assume they will be looking through a 1000BASE-T lens
 - Consider how time-to-link is affected when developing and evaluating 2.5/5GBASE-T autonegotiation proposals

Thank You!

Questions?