PLCA Timing Constraints

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1 Summary

For the 10BASE-T1S delay constraints, we refer to the following copy of Table 147-6 in Clause 147.11 of Draft 3.0. The parameters were added to simplify referencing of specific timing events in the table.

Table 147-6—10BASE-T1S delay constraints

Event	Parameter	Minimum value	Maximum value	Unit of measure	Input timing reference	Output timing reference
TX_EN sampled to MDI output	$t_{txenmdi}$	120	440	ns	Rising edge of MII_TXCLK	First DME clock transition at the MDI
TX_EN sampled to CRS asserted	$t_{txencrsa}$	0	1040	ns	Rising edge of MII_TXCLK	Rising edge of CRS
TX_EN sampled to CRS deasserted	$t_{txencrsd}$	880	1920	ns	Rising edge of MII_TXCLK	Falling edge of CRS
MDI input to CRS asserted	$t_{mdicrsa}$	400	1040	ns	First DME clock transition at the MDI	Rising edge of CRS
MDI input to CRS deasserted	$t_{mdicrsd}$	640	1120	ns	Last DME encoded zero clock transition at the MDI	Falling edge of CRS
MDI input to COL asserted	$t_{mdicola}$	0	25.6	µs	Start of corrupted transmitted signal at the MDI	Rising edge of COL
MDI input to COL deasserted	$t_{mdicold}$	0	3.2	µs	End of transmission at the MDI	Falling edge of COL
MDI input to RX_DV asserted	$t_{mdirxdva}$	2.4	4	µs	First DME clock transition at the MDI	Rising edge of RX_DV
MDI input to RX_DV deasserted	$t_{mdirxdvd}$	640	1900	ns	Last DME encoded zero clock transition at the MDI	Falling edge of RX_DV

2 Derivation of PLCA timing requirements

The derivation of PLCA timing requirements begins with the need for all PHYs on a mixing segment to detect when another PHY has begun transmitting before their transmit opportunity counter expires. We start the process with PHY A ending the transmission of a packet onto the medium. Depending on their location on the mixing segment and their CRS de-assertion delay, each PHY will start their transmit opportunity counter at a different time. If PHY B begins transmitting to commit to its transmit opportunity, its signal must be received and CRS asserted on all other PHYs on the segment **before** their transmit opportunity counter expires. From this, we can derive a timing equation which must be met for PLCA to function properly on the mixing segment.

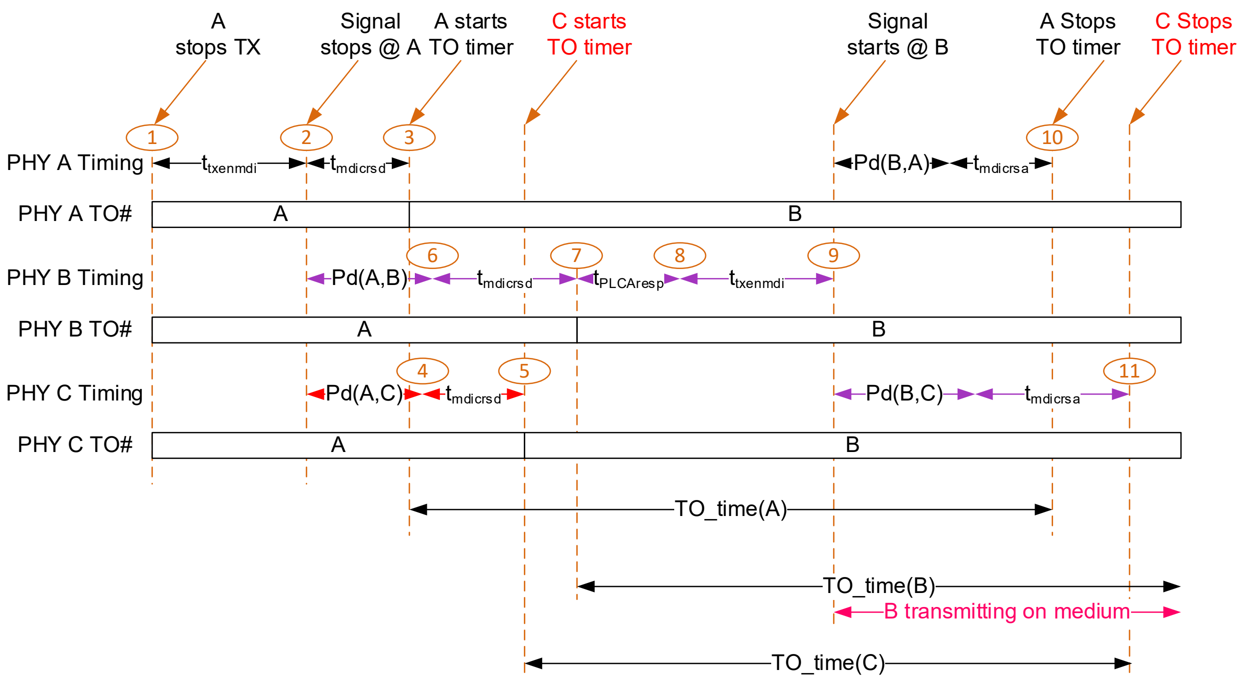

Figure 1 – Timing diagram for computation of transmit opportunity periods along a mixing segment.

1. PLCA RS on A negates TXEN and stops transmitting at the MII.
2. MDI at A goes silent following a delay through the PHY.
3. After the CRS deassertion delay, A will negate CRS on the MII. The PLCA RS on A starts it's TO timer, TO_time(A), for the next transmit opportunity.
4. After a delay of propagation through the physical medium, Pd(A,C), the MDI at C goes silent.
5. C deasserts CRS after a delay and the PLCA RS starts it's TO timer, TO_time(C), for the next transmit opportunity.
6. After a simultaneous delay of propagation through the physical medium, Pd(A,B), the MDI at B goes silent. Due to the different relative location of PHY B and C relative to PHY A, the propagation delays will be different.
7. B negates CRS after a delay and the PLCA RS starts it's TO timer, TO_time(B), for the next transmit opportunity.
8. Following a delay of the PLCA RS to the MII interface (time since reception of last data from previous transmit opportunity on MII prior to allowing MAC to transmit), the MAC B asserts TXEN to begin transmitting. Typically, this delay is assumed to be zero as the PLCA RS knows when a packet is available to be transmitted and can react immediately.

9. B begins transmitting at its MDI and committing to its transmit opportunity.
10. After a delay of propagation through the medium from B to A, Pd(B,A) and a delay of carrier detect from the MDI to assertion of CRS, PHY A will stop its TO timer. At this point PHY A has recognized that PHY B has committed to its transmit opportunity.
11. Similarly, following a delay of propagation through the medium from B to C, Pd(B,C) and a delay of carrier detect from the MDI to assertion of CRS, PHY C will stop its TO timer. At this point PHY C recognizes that PHY B has committed to its transmit opportunity.

We wish to know how long it will take for PHY C to "hear" PHY B and recognize has started to transmit and committing to its transmit opportunity. This must occur before PHY C's transmit opportunity counter expires.

All times below are relative to the time at which PHY A stops transmitting at its MDI. The time at which each PHY begins its transmit opportunity counter ($t_{TOstartN}$) is the sum of the propagation delay of the MDI at A going silent to the MDI at each of the other PHYs plus the delay of carrier detection and deassertion of CRS at the MII. When CRS is deasserted, the PLCA RS will start its transmit opportunity timer. See timing identifiers (3), (5), and (7) in the diagram above.

$$t_{TOstartA} = t_{mdicrsd} \quad (2\text{-}1)$$

$$t_{TOstartB} = Pd(A,B) + t_{mdicrsd} \quad (2\text{-}2)$$

$$t_{TOstartC} = Pd(A,C) + t_{mdicrsd} \quad (2\text{-}3)$$

Once PHY B detects PHY A going silent, it will deassert CRS and start its transmit opportunity counter at (7). If a packet is waiting to be transmitted, the PLCA RS at B may begin transmitting after a PLCA response time delay (typically zero) and the transmit delay through the PHY to the MDI. The time at which PHY B begins to transmit (and commit to its transmit opportunity) is given by t_{txB} below.

$$t_{txB} = t_{TOstartB} + t_{PLCAresp} + t_{txenmdi} \quad (2\text{-}4)$$

When PHY B beings transmitting and committing to its transmit opportunity, every other PHY on the mixing segment will "hear" PHY B transmitting after a delay of propagation through the medium plus a delay of carrier detect through the PHY to the assertion of CRS. At this time, t_{NrxB}, the PLCA RS will halt its transmit opportunity timer and recognize that PHY B has seized its transmit opportunity. PHY A hears PHY B transmitting at (10) and PHY C hears PHY B transmitting at (11).

$$t_{TOendA} = t_{ArxB} = t_{txB} + Pd(B,A) + t_{mdicrsa} \quad (2\text{-}5)$$

$$t_{TOendC} = t_{CrxB} = t_{txB} + Pd(B,C) + t_{mdicrsa} \quad (2\text{-}6)$$

When PHY C hears PHY B transmitting, its transmit opportunity counter will be at TO_{timeC}. The period of time given by TO_{timeC} is derived as follows:

$$\begin{aligned} TO_{timeC} &= t_{TOendC} - t_{TOstartC} \\ &= [t_{txB} + Pd(B,C) + t_{mdicrsa}] - [Pd(A,C) + t_{mdicrsd}] \\ &= [Pd(A,B) + t_{mdicrsd} + t_{PLCAresp} + t_{txenmdi} + Pd(B,C) + t_{mdicrsa}] - [Pd(A,C) + t_{mdicrsd}] \end{aligned} \quad (2\text{-}7)$$

Rearranging and grouping:

$$TO_{timeC} = Pd(A,B) + t_{mdicrsd} + t_{PLCAresp} + t_{txenmdi} + Pd(B,C) + t_{mdicrsa} - Pd(A,C) - t_{mdicrsd} \quad (2\text{-}8)$$

$$TO_{timeC} = [Pd(A,B) + Pd(B,C) - Pd(A,C)] + [t_{mdicrsd} + t_{PLCAresp} + t_{txenmdi}] + [t_{mdicrsa} - t_{mdicrsd}] \quad (2\text{-}9)$$

The transmit opportunity expiration, specified as TO_{time}, must be configured identically among all PHYs on the mixing segment. PHY C must receive from PHY B before its transmit opportunity timer expires. The transmit opportunity counter at C, TO_{timeC}, must then be less than the transmit opportunity time, TO_{time}, in order for the transmit opportunity counter at C to not expire before recognizing that B has seized its transmit opportunity. Additionally, PHY C cannot "hear" PHY B beginning to transmit before it "hears" PHY A first go silent so PHY C's transmit opportunity counter must be greater than zero. Therefore:

$$0 < TO_{timeC} < TO_{time} \tag{2-10}$$

Substituting (2-9) for TO_{timeC} into (2-10) yields the constraints that must be met for PLCA to function on a mixing segment.

$$0 < [Pd(A,B) + Pd(B,C) - Pd(A,C)] + [t_{mdicrsd} + t_{PLCAresp} + t_{txenmdi}] + [t_{mdicrsa} - t_{mdicrsd}] < \mathrm{TO}_{\mathrm{time}} \tag{2-11}$$

The first term, $[Pd(A,B) + Pd(B,C) - Pd(A,C)]$, contains the lump sum of the propagation delay of signals through the medium.

The second term, $[t_{mdicrsd} + t_{PLCAresp} + t_{txenmdi}]$, is the length of time from which PHY B detects that PHY A has stopped transmission and when PHY B begins transmission. As the PLCA RS knows when a packet is waiting to be transmitted and may begin to COMMIT as soon as its transmit opportunity counter begins, we set $t_{PLCAresp} = 0$.

The third term, $[t_{mdicrsa} - t_{mdicrsd}]$, is the skew between PHY C asserting and deasserting CRS after a signal appearing/disappearing from its MDI.

2.1 Computation of Transmit Opportunity TO_{time}

The solution to the maximum side of the inequality provides the minimum amount of time for a transmit opportunity. For the calculation of the we begin with the equation (2-11)

$$[Pd(A,B) + Pd(B,C) - Pd(A,C)] + [t_{mdicrsd} + t_{txenmdi}] + [t_{mdicrsa} - t_{mdicrsd}] < \mathrm{TO}_{\mathrm{time}} \tag{2-12}$$

The worst-case total propagation delay from A (going silent), B (detecting silence), B transmitting, to C (detecting B transmitting) will occur when PHY A is at one end of the segment, PHY B is at the other end of the segment, and PHY C is next to PHY A and shown in Figure 2.

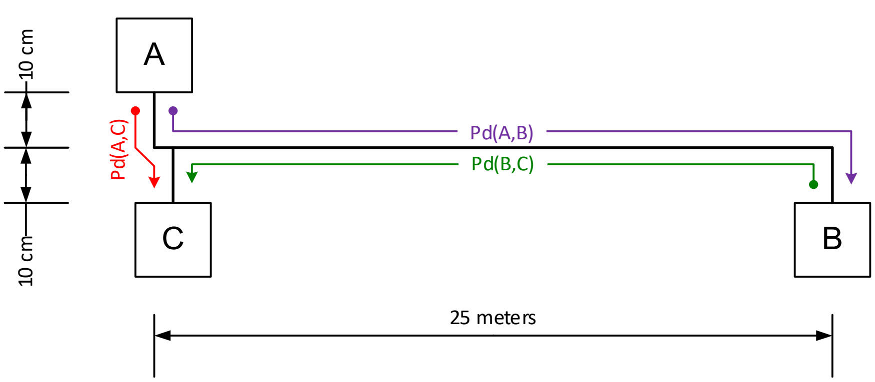

Figure 2 - Worst case maximum propagation delay topology

With PHYs A & C very close together (i.e., a minimum of 2*10 cm stubs), we can assume the propagation delay, Pd(A,C), is near zero compared to the propagation delay to the other end of the segment. Up to this point we have been determining how long it would take for PHY C to recognize that PHY B has seized its transmit opportunity. In fact, the worse-case timing would be actually when PHY A itself must recognize that PHY B has seized its transmit opportunity. In this case we can define Pd(A,C)= 0 yielding:

$$[Pd(A,B) + Pd(B,C)] + [t_{mdicrsd} + t_{txenmdi}] + [t_{mdicrsa} - t_{mdicrsd}] < \mathrm{TO}_{\mathrm{time}} \qquad (2\text{-}13)$$

We now maximize the left hand side:

$$\max(Pd(A,B) + Pd(B,C)) + \max(t_{mdicrsd}) + \max(t_{txenmdi}) + \max(t_{mdicrsa}) - \min(t_{mdicrsd}) < \mathrm{TO}_{\mathrm{time}} \qquad (2\text{-}14)$$

Define Pd_{max} as the maximum propagation delay through the medium between any two nodes, i.e., the propagation delay from one end of the segment to the opposite end. Substituting the maximum end-to-end segment propagation delay, Pd_{max}, for Pd(A,B) and Pd(B,C) while remembering that PHY C may in fact be PHY A:

$$\mathrm{TO}_{\mathrm{time}} > 2 \cdot Pd_{max} + \max(t_{mdicrsd}) + \max(t_{txenmdi}) + \max(t_{mdicrsa}) - \min(t_{mdicrsd}) \qquad (2\text{-}15)$$

Equation (2-15) yields the minimum TO_{time} for the mixing segment.

2.2 Computation of Transmit Opportunity "Gap" time

The calculation begins with the equation (2-11).

$$0 < [Pd(A,B) + Pd(B,C) - Pd(A,C)] + [t_{mdicrsd} + t_{txenmdi}] + [t_{mdicrsa} - t_{mdicrsd}] < \mathrm{TO}_{\mathrm{time}} \qquad (2\text{-}16)$$

The smallest total propagation delay from A (going silent), B (detecting silence), B transmitting, to C (detecting B transmitting) will occur when PHY A is at one end of the segment, PHY C is at the other end of the segment, and PHY B is next to PHY A and shown in Figure 2.

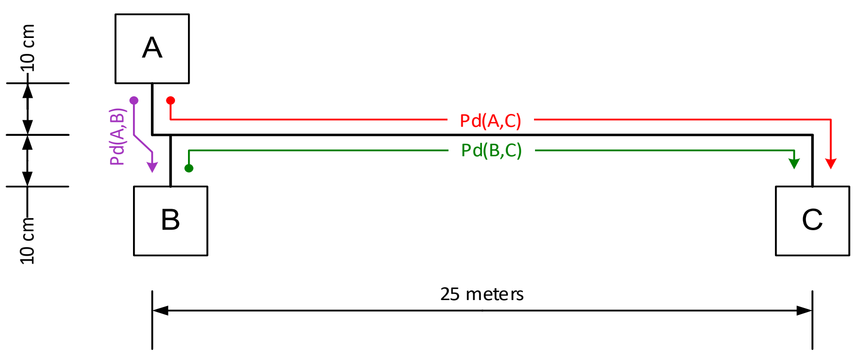

Figure 3 - Worst case maximum propagation delay topology

With PHYs A & B very close together (i.e., a minimum of 2*10 cm stubs), we can assume the propagation delay, Pd(A,B) is near zero compared to the propagation delay to the other end of the segment. Therefore we can define Pd(A,B)= 0.

We have been determining how long it would take for PHY C to "hear" PHY B and recognize that it has seized its transmit opportunity. The propagation time for C to recognize at its MDI that PHY A has stopped transmitting is Pd(A,C) and the propagation time for C to recognize that B has started transmitting is

Pd(B,A). Since PHY C is nearly the same distance from both PHYs A and B then Pd(A,C) is nearly equal to Pd(B,A). With Pd(A,C) = Pd(B,C) there is effectively an electrical race down the wire from PHY A going silent and PHY B transmitting to PHY C's MDI.

Given that Pd(A,B)=0, and Pd(B,C)-Pd(A,C)=0 we can reduce (2-16) above:

$$0 < [t_{mdicrsd} + t_{txenmdi}] + [t_{mdicrsa} - t_{mdicrsd}] \qquad (2\text{-}17)$$

Minimizing the right hand side:

$$0 < \min(t_{mdicrsd}) + \min(t_{txenmdi}) + \min(t_{mdicrsa}) - \max(t_{mdicrsd}) \qquad (2\text{-}18)$$

Equation (2-18) specifies the PHY timing requirements necessary for PHY C to properly detect the beginning next transmit opportunity when PHY A has stopped transmitting before PHY B has begun transmitting.

3 Determination of minimum default TO_{time}

The minimum time for a transmit opportunity was derived in (2-15):

$$\mathrm{TO}_{\mathrm{time}} > 2 \cdot Pd_{max} + \max(t_{mdicrsd}) + \max(t_{txenmdi}) + \max(t_{mdicrsa}) - \min(t_{mdicrsd}) \quad (3\text{-}1)$$

Assuming a slowest velocity factor of 66% within the transmit medium, the maximum propagation delay between any two PHYs on a maximum length 25 m segment will be:

$$Pd_{max} = 25/0.66c = 125 \text{ ns} \quad (3\text{-}2)$$

Substituting (3-2) into (3-1), and expanding the timing minima and maxima from Table 147-6:

$$\begin{aligned} \mathrm{TO}_{\mathrm{time}} &> 2 \cdot 125 + 1120 + 440 + 1040 - 640 \\ \mathrm{TO}_{\mathrm{time}} &> 2210\ ns \end{aligned} \quad (3\text{-}3)$$

As each nominal bit time (BT) is 100ns, equation (3-3) yields a minimum $TO_{timeC} = 22\ BT$.

As another example, given a slower medium with a velocity factor of 44%:

$$Pd_{max} = 25/0.40c = 200 \text{ ns} \quad (3\text{-}4)$$

$$\begin{aligned} \mathrm{TO}_{\mathrm{time}} &> 2 \cdot 200 + 1120 + 440 + 1040 - 640 \\ \mathrm{TO}_{\mathrm{time}} &> 2360\ ns \end{aligned} \quad (3\text{-}5)$$

Therefore, for a 25m medium with 44% velocity factor, a minimum $TO_{timeC} = 24\ BT$ is required.

4 Draft 3.0 Editing Instructions

Editing changes:

to_timer

The transmit opportunity timer maps to aPLCATransmitOpportunityTimer. The timer value should meet Equation (148-2). ~~be long enough to allow the transmitting node to have the first nibble of its transmission (including the COMMIT request) to be received by all other PLCA RS before their own to_timer expires. This includes the worst case PHY TX and RX latency and the maximum MDI to MDI propagation delay.~~ to_timer shall be set equal across the mixing segment ~~in order~~ for PLCA to work properly.

Duration: integer number between 1 and 255, expressed in bit times.

to_timer > max(2 * t_propdelay) + max(TX_EN sampled to MDI output) + max(MDI input to CRS asserted) + max(MDI input to CRS deasserted) – min(MDI input to CRS deasserted) (148-2)

where:

t_propdelay is the propagation delay between any two nodes on the mixing segment, and the delay specifications are the maxima and minima for the PHY type on the mixing segment (for 10BASE-T1S, see 147.11).

Resulting Text:

to_timer

The transmit opportunity timer maps to aPLCATransmitOpportunityTimer. The timer value should meet Equation (148-2). to_timer shall be set equal across the mixing segment for PLCA to work properly.

Duration: integer number between 1 and 255, expressed in bit times.

to_timer > max(2 * t_propdelay) + max(TX_EN sampled to MDI output) + max(MDI input to CRS asserted) + max(MDI input to CRS deasserted) – min(MDI input to CRS deasserted) (148-2)

where:

t_propdelay is the propagation delay between any two nodes on the mixing segment, and the delay specifications are the maxima and minima for the PHY type on the mixing segment (for 10BASE-T1S, see 147.11).