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Relation between IEEE P802.1AS and IEEE Std 802.3 PHY delay – Part II

TSN Working Group

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contribution to IEEE

part I: https://www.ieee802.org/1/files/public/docs2026/as-Turner-PHYdelay-dot3-0526-V2.pdf

Reference planes in Figure 8-2

$$\text{egressTimestamp} = \text{egressMeasuredTimestamp} + \text{egressLatency}$$

$$\text{ingressTimestamp} = \text{ingressMeasuredTimestamp} - \text{ingressLatency}$$

where the timestamps relative to the reference plane, egressTimestamp and ingressTimestamp, are computed from the timestamps relative to the timestamp measurement plane, egressMeasuredTimestamp and ingressMeasuredTimestamp, respectively, using their respective latencies, egressLatency and ingressLatency. Failure to make these corrections results in a time offset between the timeReceiver and timeTransmitter clocks.

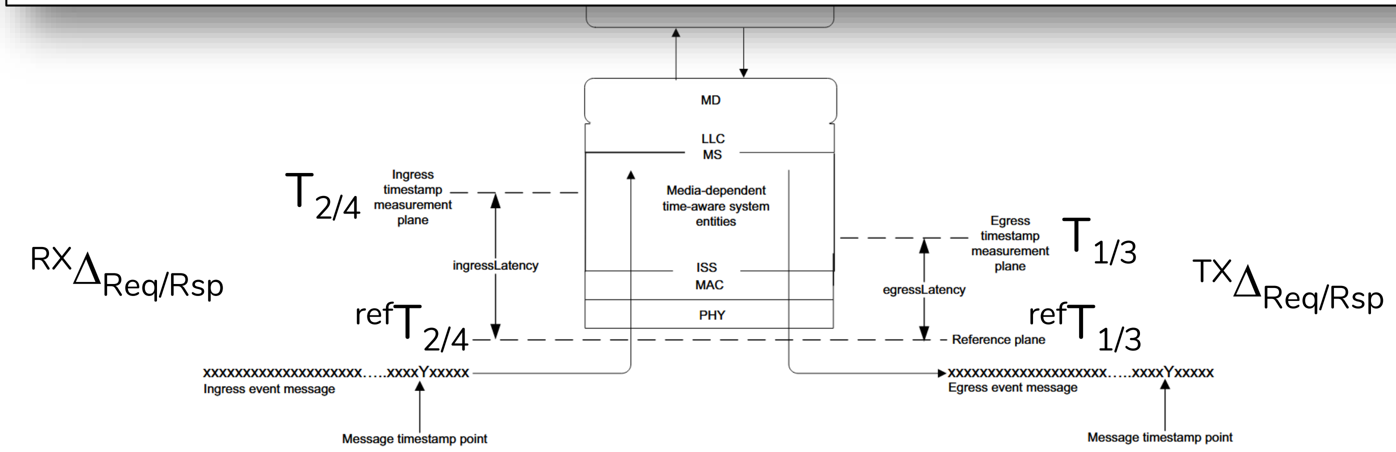

Figure 8-2—Definition of message timestamp point, reference plane, timestamp measurement plane, and latency constants

It is advised to use the ingress and egress timestamping measurement planes recommended by the specification for the medium used. For example, for IEEE 802.3 networks, the recommendation is to follow Clause 90 of IEEE Std 802.3-2022, as amended by IEEE Std 802.3cx-2023, IEEE Std 802.3de-2022, and IEEE Std 802.3df-2024.

- The ingress/egressLatencies of Figure 8-2 must be taken from a PHY data sheet and are therefore in TAI units

- T .. denotes time stamps in local clock units
- t' ... denotes times in synchronized time units
- t ... denotes times in TAI time units
- Δ ... are in in TAI time units

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11.2.19.3.4 computePropTime():

11.2.19.3.4 computePropTime(): Computes the mean propagation delay on the PTP Link attached to this MD entity, D, and returns this value. D is given by Equation (11-5).

$$D = \frac{r \times (t_4 - t_1) - (t_3 - t_2)}{2} \tag{11-5}$$

where

- t_4 is pdelayRespEventIngressTimestamp (see 11.3.2.1) for the Pdelay_Resp message received in response to the Pdelay_Req message sent by the MD entity, in nanoseconds; the pdelayRespEventIngressTimestamp is equal to the timestamp value measured relative to the timestamp measurement plane, minus any ingressLatency (see 8.4.3)
- t_1 is pdelayReqEventEgressTimestamp (see 11.3.2.1) for the Pdelay_Req message sent by the peer-to-peer Port entity, in nanoseconds
- t_2 is the sum of (1) the ns field of the requestReceiptTimestamp, (2) the seconds field of the requestReceiptTimestamp multiplied by 10^9, (3) the correctionField multiplied by s (see 11.2.19.2.13) and then divided by 2^{16} (i.e., the correctionField is expressed in nanoseconds plus fractional nanoseconds), of the Pdelay_Resp message received in response to the Pdelay_Req message sent by the MD entity, and (4) –delayAsymmetry divided by 2^{16} if this state machine is invoked by CMLDS (i.e., delayAsymmetry is subtracted in the case of CMLDS)
- t_3 is the sum of (1) the ns field of the responseOriginTimestamp, (2) the seconds field of the responseOriginTimestamp multiplied by 10^9, and (3) the correctionField divided by 2^{16} (i.e., the correctionField is expressed in nanoseconds plus fractional nanoseconds), of the Pdelay_Resp_Follow_Up message received in response to the Pdelay_Req message sent by the MD entity
- r is the current value of nrrPdelay for this MD entity (see 11.2.13.14)

NOTE 1—Equation (11-5) defines D as the mean propagation delay relative to the time base of the time-aware system at the other end of the attached PTP Link. It is divided by nrrPdelay (see 11.2.13.14) to convert it to the time base of the current time-aware system when subtracting from syncEventIngressTimestamp to compute upstreamTxTime [see item i) in 11.2.14.2.1].

- The time-stamps of Equation (11-5) are assumed to have been taken at the reference plane depicted in Figure 8-2
- The mean propagation delay of Equation (11-5) is in units of the local clock at the upstream time-aware system, as stated in Note 1

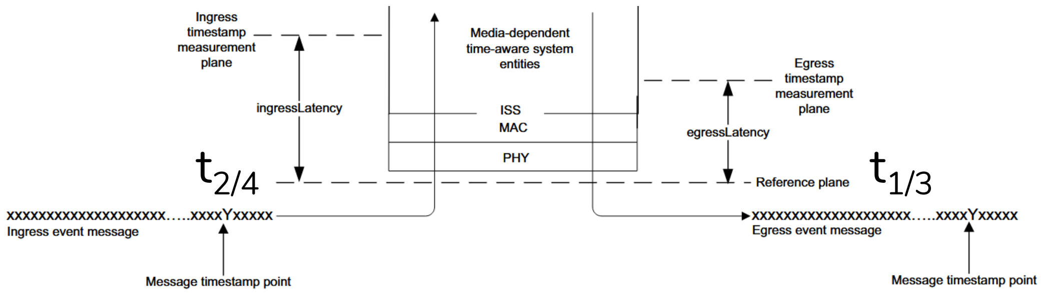

Figure 8-2—Definition of message timestamp point, reference plane, timestamp measurement plane, and latency constants

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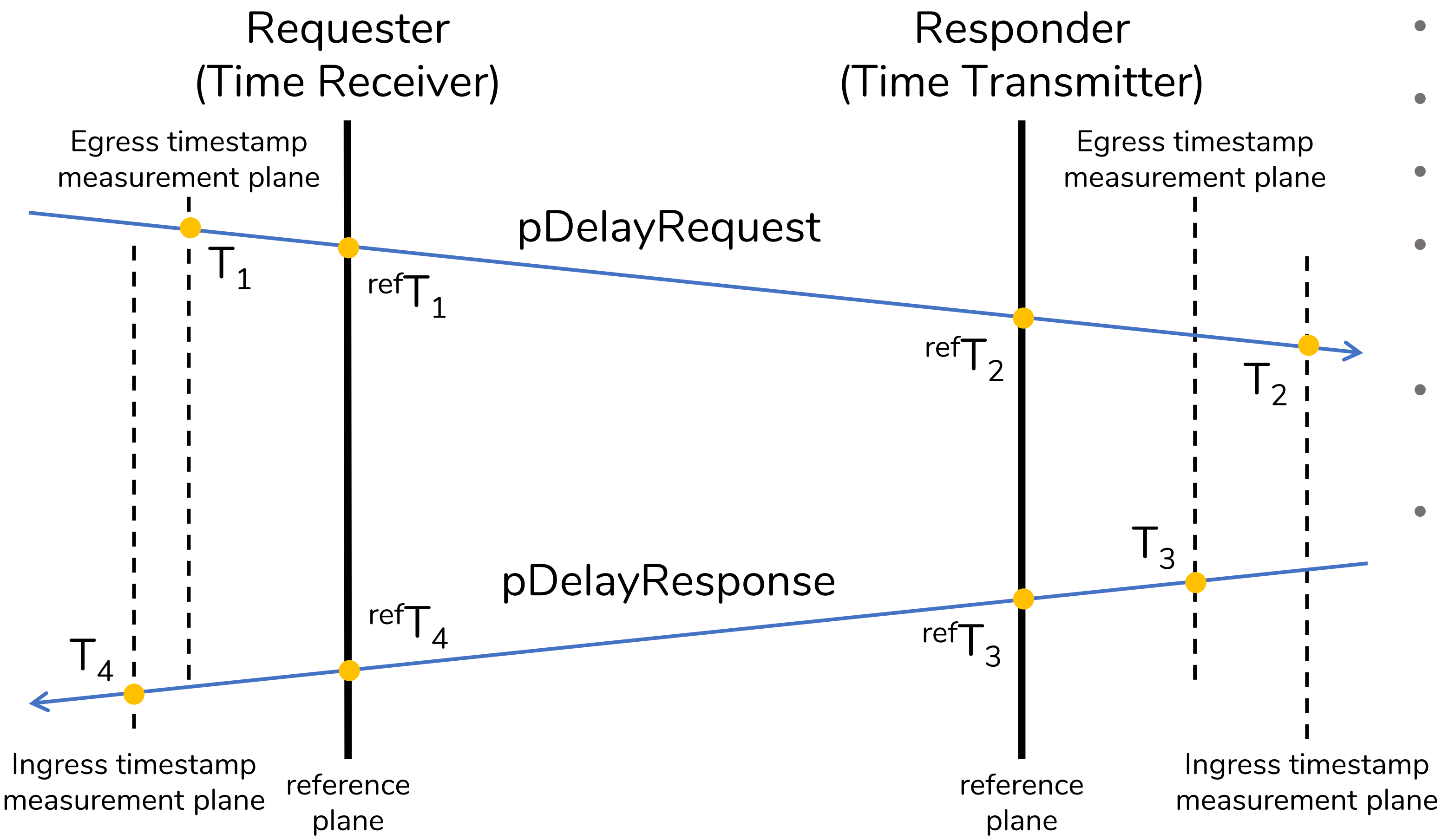
pDelay Measurement



- ${}^{ref}T_1 = T_1 + {}^{TX}\Delta_{Req}$
- ${}^{ref}T_2 = T_2 - {}^{RX}\Delta_{Rsp}$
- ${}^{ref}T_3 = T_3 + {}^{TX}\Delta_{Rsp}$
- ${}^{ref}T_4 = T_4 - {}^{RX}\Delta_{Req}$

- T .. denotes time stamps in local clock units
- Δ ... are in TAI time units from data sheet

Reference Plane in Mean Link Delay

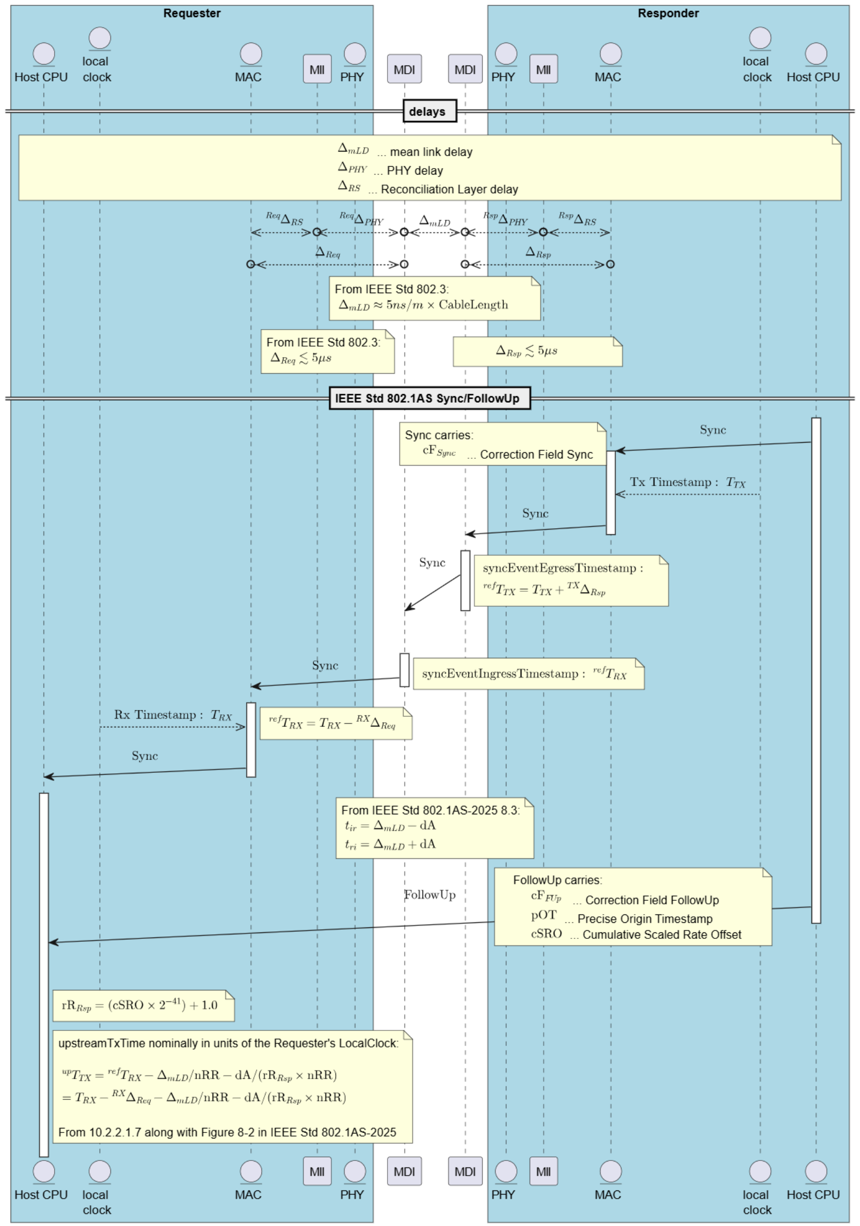
- equation (11-5):

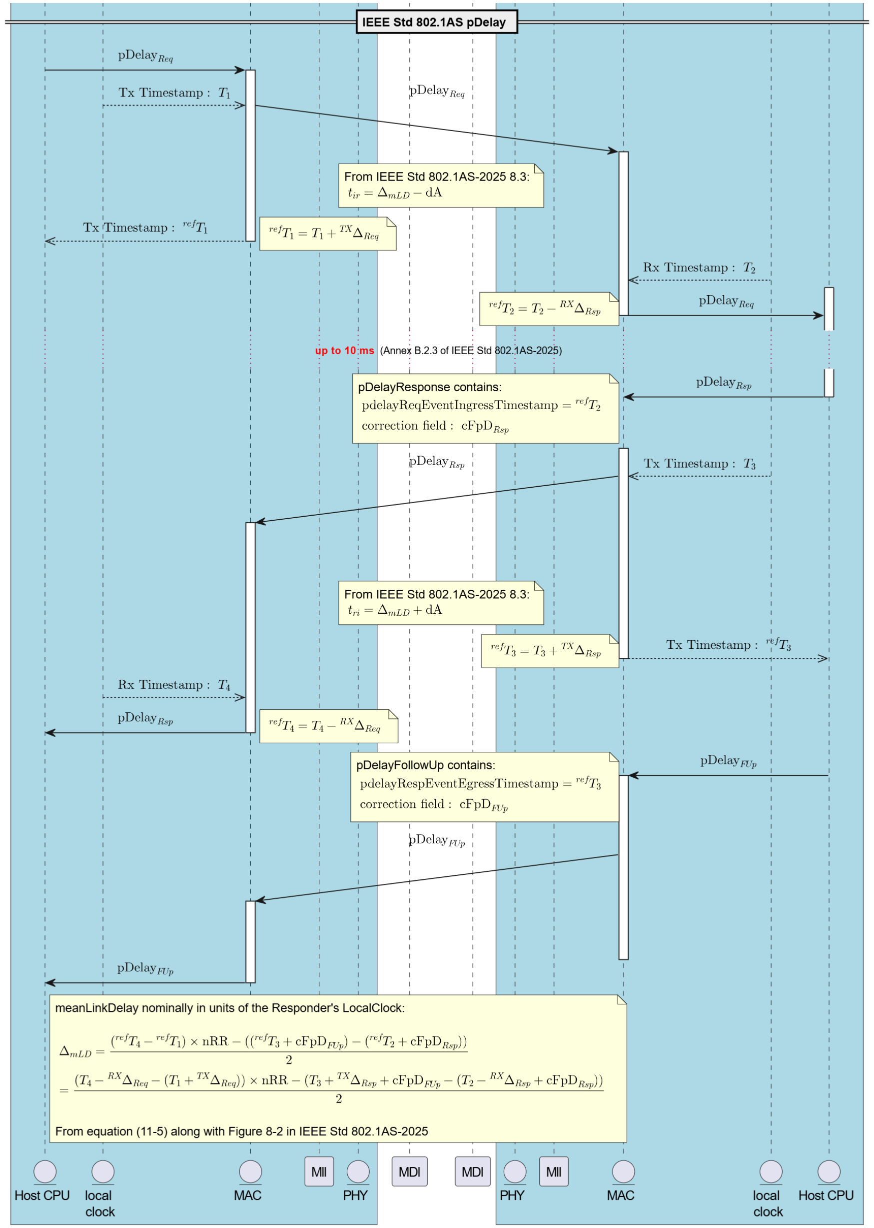
  $^{rsp}D = 1/2 \times ((^{ref}T_4 - {}^{ref}T_1) \times nRR - (^{ref}T_3 - {}^{ref}T_2))$

  $= 1/2 \times ((T_4 - {}^{RX}\Delta_{Req} - (T_1 + {}^{TX}\Delta_{Req})) \times nRR - (T_3 + {}^{TX}\Delta_{Rsp} - (T_2 - {}^{RX}\Delta_{Rsp})))$

- ^{rsp}D … the mean link delay calculated at the Requester in units of the LocalClock at the Responder (sic?)
- T .. denotes time stamps in local clock units of the time-aware system
- ^{ref}T … have been adjusted for the reference plane as per section 8.4.3
- Δ … are in in TAI time units
- nRR … neighbor rate ratio
- *(ignoring correctionFields)*

- **The implicit terms $^{T/RX}\Delta_{Req/Rsp} \times nRR$ seem to add a systematic error**





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8.3 Link asymmetry

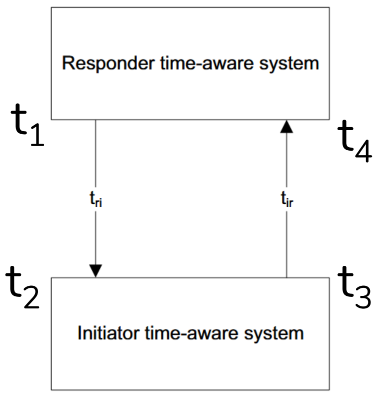

Figure 8-1—Propagation asymmetry

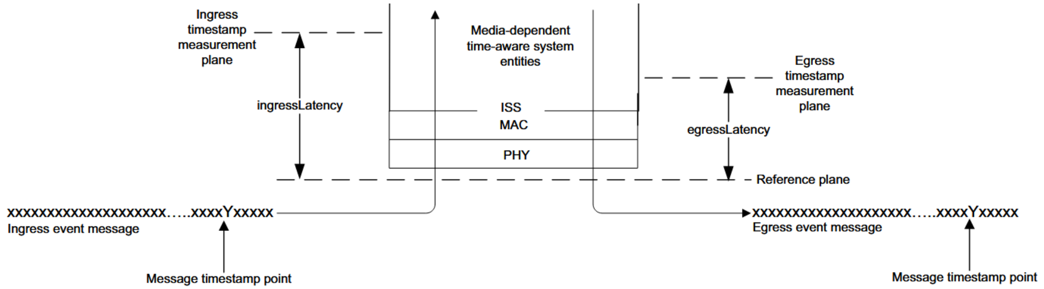

Figure 8-2—Definition of message timestamp point, reference plane, timestamp measurement plane, and latency constants

The meanLinkDelay is the mean value of t_{ir} and t_{ri}, i.e., meanLinkDelay = $(t_{ir} + t_{ri})$ / 2. The delayAsymmetry is defined as:

t_{ir} = meanLinkDelay – delayAsymmetry

t_{ri} = meanLinkDelay + delayAsymmetry

$$dA = (t_{ri} - t_{ir})/2$$

10.2.5.9 delayAsymmetry: The asymmetry in the propagation delay on the link attached to this port. If propagation delay asymmetry is not modeled, then delayAsymmetry is zero. There is one instance of this variable for CMLDS (see 11.2.17), and there is also one instance of this variable for each domain. The instance of this variable for CMLDS is relative to the local clock. The instance of this variable for each domain is relative to the grandmaster time base for that domain. The instance of delayAsymmetry for CMLDS is used where needed in all computations done by the CMLDS, and also by computations using the

$$\begin{aligned} t_{ir} &= t_2 - t_1 \\ t_{ri} &= t_4 - t_3 \\ D &= \frac{t_{ir} + t_{ri}}{2} = \frac{(t_4 - t_1) - (t_3 - t_2)}{2} \end{aligned} \quad (11\text{-}1)$$

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11.1.3 Transport of time-synchronization information

The difference between mean propagation delay relative to the Grandmaster Clock time base and relative to the time bases of the PTP Instance at the other end of the attached PTP Link or of the current PTP Instance is usually negligible. The former can be obtained from the latter by multiplying the latter by the ratio of the Grandmaster Clock frequency to the frequency of the LocalClock entity of the PTP Instance at the other end of the PTP Link attached to this PTP Port. This ratio differs from 1 by 200 ppm or less. For example, for a worst-case frequency offset of the LocalClock entity of the PTP Instance at the other end of the PTP Link, relative to the Grandmaster Clock, of 200 ppm, and a measured propagation time of 100 ns, the difference in *D* relative to the two time bases is 20 ps. The corresponding difference for PTP Link delay asymmetry in this example is also negligible because the magnitude of the PTP Link delay asymmetry is of the same order of magnitude as the mean propagation time, or less. However, the difference is usually not negligible for residence time because residence time can be much larger (see B.2.2).

- This is only true if one uses the reference plain!
- If the PHY delays get included, the deviation rises to at least single digit ns

Mean Link Delay in Synchronized Time

- from equation (11-5):

  $^{rsp}D = 1/2 \times ((^{ref}T_4 - {}^{ref}T_1) \times nRR_{req} - (^{ref}T_3 - {}^{ref}T_2))$

  $\Rightarrow {}^{sync}D = rR_{rsp} \times {}^{rsp}D$

  $= (^{RX}cSRO \times 2^{-41} + 1.0)/2 \times ((^{ref}T_4 - {}^{ref}T_1) \times nRR - (^{ref}T_3 - {}^{ref}T_2))$

  $= 1/2 \times ((^{ref}T_4 - {}^{ref}T_1) \times rR_{req} - (^{ref}T_3 - {}^{ref}T_2) \times rR_{rsp})$

- $nRR_{req} = R_{rsp} / R_{req}$
- $rR_{rsp} = R_{GM} / R_{rsp}$
- $rR_{req} = R_{GM} / R_{rsp}$

- ^{rsp}D … the mean link delay calculated at the Requester in units of the LocalClock at the Responder (sic?)
- ^{sync}D … the mean link delay calculated at the Requester in units of synchronized time (sic?)
- $^{RX}cSRO$ … the Cumulative Scaled Rate Offset received at the Requester in the last Sync Message from the Responder acting as the TimeTransmitter (equivalent to the RateRatio at the Responder rR_{rsp})