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Amendment 1

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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Packet over Transport aspects – Synchronization, quality and availability targets

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Definitions and terminology for synchronization in packet networks

Amendment 1

CAUTION !

PREPUBLISHED RECOMMENDATION

This prepublication is an unedited version of a recently approved Recommendation. It will be replaced by the published version after editing. Therefore, there will be differences between this prepublication and the published version.

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Amendment 1 to Recommendation ITU-T G.8260 (2015)

Definitions and terminology for synchronization in packet networks: Amendment 1

Summary

Amendment 1 to Recommendation ITU-T G.8260 (2015) provides the following update:

- adds definitions to clause 3.1
- replaces clause 6.6 to cover both forward and reverse time error measurements
- corrects the association of minimum delay with the forward and reverse time error sequences in clauses I.3.2, and their use in subsequent clauses I.3.2.1, I.3.2.3, I.4.1.2, I.4.2.1.1 and I.4.2.1.3
- replaces the term "time offset" with "two-way time error" in clauses I.3.4 and I.4.4

Amendment 1 to Recommendation ITU-T G.8260 (2015)

Definitions and terminology for synchronization in packet networks: Amendment 1

1 Clause 3.1

Add the following definitions to Clause 3.1:

3.1.21 message timestamp point: See definition in [IEEE1588], clause 3.1.18

3.1.22 reference plane: The boundary between a port of a PTP clock and the network physical medium. Timestamp events occur as messages cross this interface.

3.1.23 timestamp measurement plane: The plane at which timestamps are captured. If the timestamp measurement plane is different from the reference plane, the timestamp is corrected for ingress latency and/or egress latency.

2 Clause 6.6

Replace clause 6.6 with the following:

6.6 Packet timing signal equipment interface characterization

The configuration described in clause 6.5 for measuring packet delay variation can be extended to measurement of the packet timing signal at an equipment interface. In this case, the packet timestamper with reference is connected directly to the packet timing signal interface with no intervening network.

A configuration for performing such a measurement is shown in Figure 10 below. The packet time-error signals resemble the time error function *x(t)* described in clause 4.5.13 of G.810. For each packet, a difference is computed between the timestamp from the device and the timestamp taken on that same packet from the packet timestamper (PT) with reference (R). This is true for the streams in both directions with the details of the difference operations indicated in the figure.

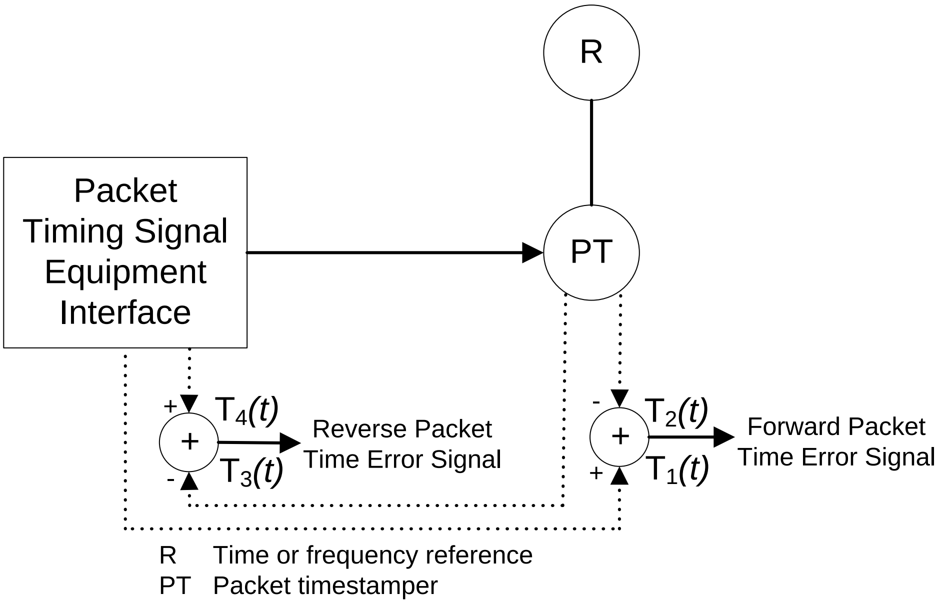

Figure 10 – Configuration for packet timing signal equipment interface measurement

3 Clauses I.3.2, I.3.2.1, and I.3.2.3

Replace clauses I.3.2, I.3.2.1 and I.3.2.3 with the following:

(Note: clauses I.3.2.2 and I.3.2.4 are unaffected)

I.3.2 Packet selection methods

Four examples of packet selection methods are described in the clauses that follow. The first two, minimum packet selection and percentile average packet selection, focus on packet data at the floor delay. The second two, band average packet selection and cluster range packet selection, can be applied either at the floor delay or at some other region.

Equation (I-4) defines that the reverse time errors are the same as the reverse delays. Thus, the minimum time error values correspond to the floor delays. However, Eq. (I-3) defines that the forward time errors are the inverse of forward delays. Thus, the maximum time error values correspond to floor delays.

I.3.2.1 Minimum packet selection method

The minimum packet selection method involves selecting the minimum delayed packet, i.e. the maximum or minimum value within a section of forward or reverse time error data, correspondingly. This can be represented as

$$x_{\min}(i) = -\min\left[-x_F(j)\right] \; for \; (i \le j \le i+n-1) \tag{I-8}$$

when using the forward time error sequence and

$$x_{\min}(i) = \min\left[x_R(j)\right] \text{for} \; (i \le j \le i+n-1) \tag{I-8a}$$

when using the reverse time error sequence.

I.3.2.3 Band average packet selection method

The band average packet selection method can be used to select a section of packet data at the floor or from some other region such as the ceiling or somewhere else above the floor. The band is defined by two percentile values representing the upper and lower selection bounds. To perform the band average packet selection, it is first necessary to represent the sorted packet time-error sequence. Let x'' represent this sorted phase sequence from minimum to maximum for the reverse time error sequence, and maximum to minimum for the forward time error sequence, over the range $i \le j \le i + n - 1$. Next, it is necessary to represent the indices that are themselves set based on the selection of the two percentile values.

Let a and b represent indices for the two selected percentile values. The averaging is then applied to the x'' variable indexed by a and b. The number of averaged points m is related to a and b: $m = b - a + 1$.

$$x'_{band\_avg}(i) = \frac{1}{m} \sum_{j=a}^{b} x''_{j+i} \qquad \text{(I-9)}$$

Each of the indices a and b is determined by rounding to find the closest index to the desired percentile value. The additional constraint is that both indices have a minimum value of the first index and a maximum value of the last index. Further, at least one point within the data set must be selected. Thus, for example, a set of ten points with the percentile values set to 0% and 2% (0.02), both a and b would be set to the minimum index so that at least a single point would be selected.

4 Appendix I.3.4

Replace clause I.3.4 with the following:

I.3.4 Two Way Time Error Calculation

The two-way time error sequence x_C is calculated from the forward time error sequence x_F and reverse time error sequence x_R according to the following equation:

$$x_C(n\tau_0) = \frac{x_R(n\tau_0) + x_F(n\tau_0)}{2} \qquad \text{(I-12a)}$$

where τ_0 is the mean packet spacing.

Figure I.9a shows the combination operation producing the two-way time error.

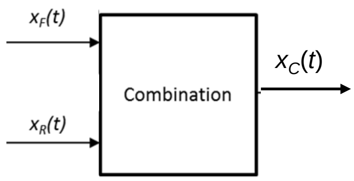

Figure I.9a – Two-way offset

When combined with packet selection, which is performed on the forward and reverse sequences independently, the packet-selected time-error sequence of the forward path, $x_F'(t)$, is combined with the packet-selected time-error sequence of the reverse path, $x_R'(t)$, to create the packet-selected two-way time error sequence $x_C'(t)$.

$$x_C'(n\tau_s) = \frac{x_R'(n\tau_s) + x_F'(n\tau_s)}{2} \qquad \text{(I-12b)}$$

where τ_s is the packet selection window width.

Figure I.10 shows that when the combination operation is preceded by packet selection, the packet-selected two-way time error sequence is produced. This can itself be optionally combined with bandwidth filtering and/or stability metrics. The sequence $x_C'(t)$ is referred to as packet-selected two-way time error (pktSelected2wayTE).

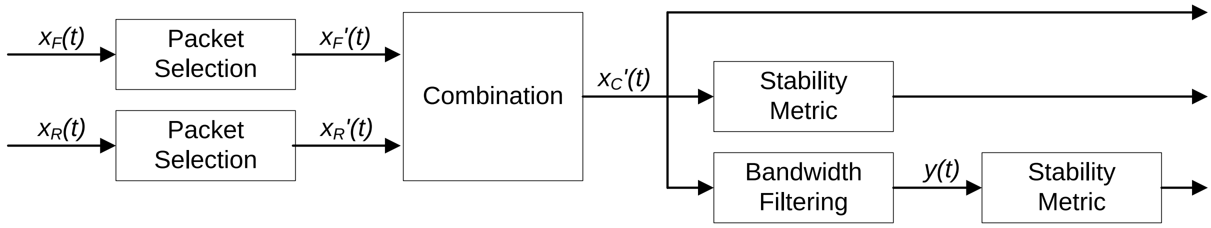

Figure I.10 – Two-way time error including packet selection and filtering

Note that the combination operation could be performed after bandwidth filtering as applied to each packet selection output separately, with the same results.

Subsequently, $x_C'(t)$ for two-way flows (or $x_C(t)$ if there is no packet selection) may be substituted into the various metrics in the same manner as $x'(t)$ for one-way flows. When used in this way, the prefix "2way" denotes the fact that the metric is computed on a two-way flow, e.g. "2wayTDEV", "pktSelected2wayMAFE", or "pktFiltered2wayMTIE".

5 Appendix I.4.1.2

Replace clause I.4.1.2 with the following:

I.4.1.2 minMATIE

The packet selection operation can also be integrated in the MATIE calculation. The definitions and estimator formulas for minMATIE are given as follows:

Definition

minMATIE($n\tau_0$) is defined as a specified percentile, β, of the random variable:

$$U_n = \max_{1 \le k \le N-2n+1} \left| x_{\min}(k+n) - x_{\min}(k) \right| \qquad \text{(I-16)}$$

where $x_{\min}(k)$ is as defined in equation (I-8) for the forward time error sequence, or (I-8a) for the reverse time error sequence, $n\tau_0$ is the observation window length, n is the number of samples in the window, τ_0 is the sample interval, N is the number of samples in the data set, and k is incremented for sliding the window.

Estimator formula

minMATIE($n\tau_0$) may be estimated by:

$$\text{minMATIE}(n\tau_0) \cong \max_{1 \le k \le N-2n+1} \left| x_{\min}(k+n) - x_{\min}(k) \right| \qquad \text{(I-17)}$$

for n = 1, 2, ..., integer part (N/2)

The above is a point estimate, and is obtained for measurements (i.e. samples x_i of the packet time error sequence, which represent the data values) over a single measurement period (see Figure II.1 of ITU-T G.810). Estimates of minMATIE (for specified N, $\tau = n\tau_0$, and β), and their respective degrees of statistical confidence, may be obtained from measured data if measurements are made for multiple measurement periods (see clause II.5 of [ITU-T G.810]).

6 Appendix I.4.2.1.1

Replace I.4.2.1.1 with the following:

I.4.2.1.1 MinTDEV

Definition

The minTDEV operator has been defined based on the TDEV metric. The TDEV metric is shown below in equation (I-21):

$$\sigma_x(\tau) = \mathrm{TDEV}(\tau) = \sqrt{\frac{1}{6n^2}\left\langle\left[\sum_{i=1}^{n}(x_{i+2n} - 2x_{i+n} + x_i)\right]^2\right\rangle} \qquad \text{(I-21)}$$

The TDEV operator is based on the mean of the sample window (equation I-22):

$$x_{mean}(i) = \frac{1}{n}\sum_{j=0}^{n-1} x_{j+i} \qquad \text{(I-22)}$$

Compared with the TDEV operator, in the minTDEV operation the mean of the sample window is replaced by $x_{\min}(i)$ as defined in I-8 for the forward time error sequence, or I-8a for the reverse time error sequence. Substituting $x_{\min}(i)$ back into original TDEV definition yields the definition of minTDEV(τ) (with $\tau = n\tau_0$):

$$\sigma_{x\_\min}(n\tau_0) = \mathrm{minTDEV}(n\tau_0) = \sqrt{\frac{1}{6}\left\langle\left[x_{\min}(i+2n) - 2x_{\min}(i+n) + x_{\min}(i)\right]^2\right\rangle}\,, \qquad \text{(I-24)}$$

for n = 1, 2, ..., integer part $\left(\frac{N}{3}\right)$

where the angle brackets denote ensemble average.

Estimator formula

minTDEV($n\tau_0$) may be estimated by:

$$\mathrm{minTDEV}(n\tau_0) \cong \sqrt{\frac{1}{6(N-3n+1)}\sum_{i=1}^{N-3n+1}\left[x_{\min}(i+2n) - 2x_{\min}(i+n) + x_{\min}(i)\right]^2} \qquad \text{(I-25)}$$

for n = 1, 2, ..., integer part $\left(\frac{N}{3}\right)$

Usage

The minTDEV operator has been indicated as a useful tool in combination with packet networks that exhibit a PDV behavior, where it is possible to identify a suitable set of packets with packet delay variation close to a minimum delay.

In fact, these packets are less impacted by the queuing delays, and therefore are more representative of the original timing. Because of its definition, the minTDEV may not fully address all network scenarios (e.g. those with two-sided PDV distributions for which minimum selection can show large variations and hence increased TDEV noise) and further study is needed.

Pros and cons

The minTDEV calculation gives information on network packet delay noise processes but is not suitable for frequency offset characterization.

Like TDEV, minTDEV is sensitive to systematic effects which could mask noise components.

Unlike TDEV, minTDEV is sensitive to a small number of outliers (low-lying in this case).

The definition of the precise aspects that create the potential sensitivities listed above and the subsequent method of handling these when applying this metric are for further study.

7 Appendix I.4.2.1.3

Replace clause I.4.2.1.3 with the following:

I.4.2.1.3 BandTDEV

Definition

BandTDEV represents the TDEV calculation where the band average selection operator (see I.3.2.3) is used to replace the mean of the sample window. The selected band is defined by two percentile values representing the upper and lower selection bounds, as shown in Equation (I-9).

bandTDEV can then be defined as:

$$\sigma_{x\_band}(\tau) = bandTDEV(\tau) = \sqrt{\tfrac{1}{6}\left\langle\left[x'_{band\_avg}(i+2n) - 2x'_{band\_avg}(i+n) + x'_{band\_avg}(i)\right]^2\right\rangle} \quad \text{(I-27)}$$

where the angle brackets denote ensemble average.

Estimator formula

bandTDEV($n\tau_0$) may be estimated by:

$$bandTDEV(n\tau_0) \cong \sqrt{\frac{1}{6(N-3n+1)}\sum_{i=1}^{N-3n+1}\left[x'_{band\_avg}(i+2n) - 2x'_{band\_avg}(i+n) + x'_{band\_avg}(i)\right]^2} \quad \text{(I-28)}$$

for $n = 1, 2, ...,$ integer part $\left(\frac{N}{3}\right)$

Usage

The bandTDEV calculation has the flexibility, in comparison to minTDEV and percentileTDEV, of being able to select a region of packet delay values away from the floor. Thus, if the population of packet delay values at the floor is noisier than the population immediately above, bandTDEV indices could be selected to focus analysis on that region.

Some of the comments on minTDEV usage apply here, but bandTDEV can apply effectively to distributions other than one-sided distributions slanted towards the packet with the minimum delay. It is particularly effective for packet delay distributions with a well-populated mode somewhere in the packet delay distribution.

Pros and cons

Like minTDEV and percentileTDEV, bandTDEV gives information on network packet delay noise processes but is not optimal for frequency offset characterization.

Like TDEV, minTDEV, and percentileTDEV, bandTDEV is sensitive to systematic effects which could mask noise components.

The definition of the precise aspects that create the potential sensitivities listed above and the subsequent method of handling these when applying this metric are for further study.

8 Appendix I.4.4

Replace clause I.4.4 with the following:

I.4.4 Metrics estimating time error

I.4.4.1 Packet-selected two-way time error (pktSelected2wayTE)

The packet-selected two-way time error sequence, $x_C'(t)$ in Figure I.11 of I.3.4, is a sequence that can be used directly as a metric estimating time error. It is referred to as pktSelected2wayTE. A graphical representation of the packet-selected two-way time error sequence is shown in Figure I.13a:

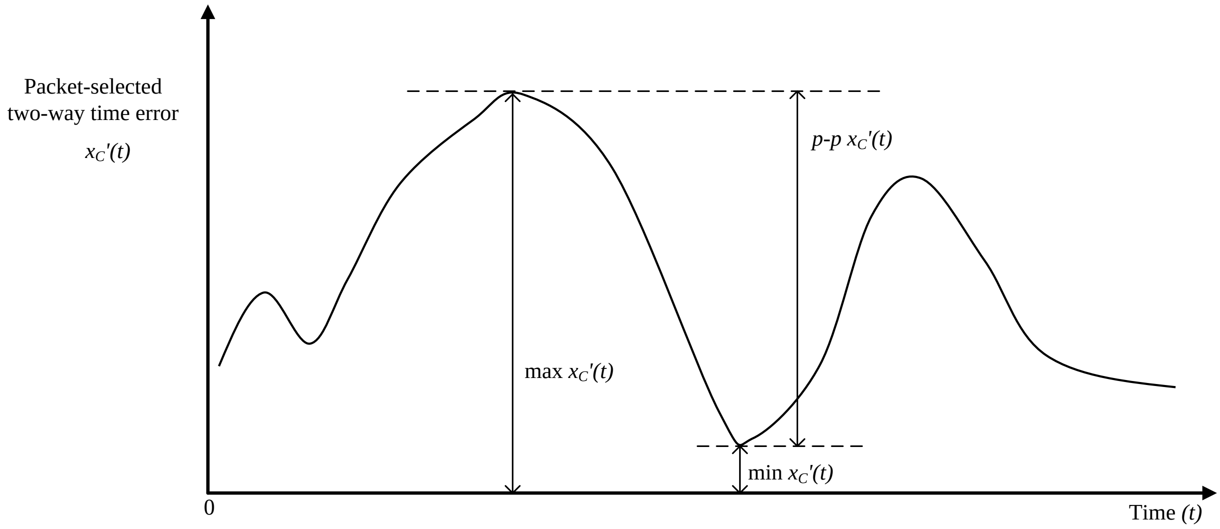

Figure I.13a – Packet-selected two-way time error sequence and derived values

Peak-to-peak packet-selected two-way time error:

$$\text{peak-to-peak}(\mathit{pktSelected2wayTE}) = \max(\mathit{pktSelected2wayTE}) - \min(\mathit{pktSelected2wayTE}) \quad \text{(I-51a)}$$

Maximum absolute packet-selected two-way time error:

$$\max|\mathit{pktSelected2wayTE}| = \max(\ |\max(\mathit{pktSelected2wayTE})|, |\min(\mathit{pktSelected2wayTE})|\ ) \quad \text{(I-51b)}$$

I.4.4.2 Packet Filtered Two-way time error (pktFiltered2wayTE)

The packet-filtered two-way time error sequence, $y(t)$ in Figure I.11 of I.3.4, is a sequence that can be used directly as a metric estimating time error. It is referred to as pktFiltered2wayTE.

Maximum absolute packet-filtered two-way time error:

$$\max|\mathit{pktFiltered2wayTE}| = \max(\ |\max(\mathit{pktFiltered2wayTE})|, |\min(\mathit{pktFiltered2wayTE})|\ ) \quad \text{(I-51c)}$$

I.4.4.3 Maximum/Minimum/Peak-to-peak average time error (maxATE, minATE, ppATE)

Definitions

For estimating how a time clock could further filter the noise in the two-way time error sequence, an averaging function can be slid over the data in a similar manner as in the bandwidth filtering function (G.8260/I.3.1.2) used for pktTIE (I.4.1.3) and other metrics.

maxATE($n\tau_S$) ("Maximum Average Time Error") is defined as a specified percentile, β, of the random variable:

$$X_n^{\max} = \max_{1 \le k \le N-n+1} \frac{1}{n} \sum_{i=k}^{n+k-1} \left(x_C'(i) \right) \quad \text{(I-52)}$$

for $n = 1, 2, ..., N$

where $x_C'(i)$ is the packet-selected two-way time error (which represents time error and is a random sequence), $n\tau_S$ is the observation window length, n is the number of packet selection windows in the observation window and consequently the number of pre-processed samples in the observation window, τ_S is the packet selection window length and consequently the time interval between delay samples after the pre-processing step of packet selection, N is the total number of pre-processed samples, and k is incremented for sliding the observation window. maxATE describes the maximum value of average packet-selected two-way time error over an observation interval of length $n\tau_S$.

Similarly, minATE($n\tau_S$) ("Minimum Average Time Error") is defined as a specified percentile, β, of the random variable:

$$X_n^{\min} = \min_{1 \le k \le N-n+1} \frac{1}{n} \sum_{i=k}^{n+k-1} \left(x_C'(i) \right) \quad \text{(I-53)}$$

for $n = 1, 2, ..., N$

where the variables are defined as above. minATE describes the minimum value of average packet-selected two-way time error over an observation interval of length $n\tau_S$.

Finally, ppATE($n\tau_S$) ("Peak-to-peak Average Time Error") is defined as a specified percentile, β, of the random variable:

$$X_n^{pp} = X_n^{\max} - X_n^{\min} = \max_{1 \le k \le N-n+1} \frac{1}{n} \sum_{i=k}^{n+k-1} \left(x_C'(i) \right) - \min_{1 \le k \le N-n+1} \frac{1}{n} \sum_{i=k}^{n+k-1} \left(x_C'(i) \right) \quad \text{(I-54)}$$

for $n = 1, 2, ..., N$

where the variables are defined as above. ppATE describes the peak-to-peak value of average packet-selected two-way time error over an observation interval of length $n\tau_S$.

Estimator formulas

For calculating maxATE the sliding window size is varied by sequencing n and determining the maximum two-way time error for each value of n, thus creating maxATE as a function of sliding averaging window width. In a similar fashion, minATE is calculated by determining the minimum two-way time error as a function of sliding averaging window width. ppATE is calculated through a point-by-point subtraction of maxATE minus minATE elements.

$$\text{maxATE}\left(n\tau_S \right) \cong \max_{1 \le k \le N-n+1} \frac{1}{n} \sum_{i=k}^{n+k-1} \left(x_C'(i) \right), \quad \text{(I-55)}$$

$$\text{minATE}\left(n\tau_S \right) \cong \min_{1 \le k \le N-n+1} \frac{1}{n} \sum_{i=k}^{n+k-1} \left(x_C'(i) \right), \quad \text{(I-56)}$$

$$\text{ppATE}\left(n\tau_S \right) = \text{maxATE}\left(n\tau_S \right) - \text{minATE}\left(n\tau_S \right) \quad \text{(I-57)}$$

for $n = 1, 2, ..., N$

where τ_S is the time interval between delay samples after packet selection. Thus τ_S is the same as the selection window size. N is the total number of samples and $x_C'(i)$ is the packet-selected two-way time error after packet selection. The resulting maxATE and minATE curves are shown in Figure I.14 along with the value of ppATE for *n*=1.

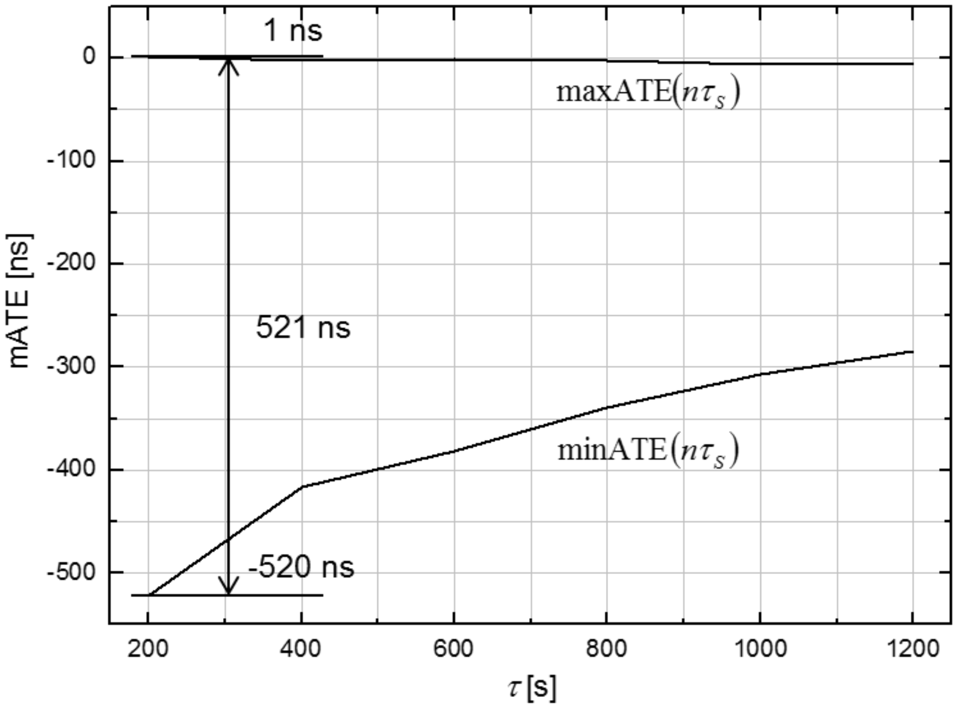

Figure I.14 – Example of Average Time Error Calculation

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