60802 Time Sync – Normative Requirements for d2.1

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Version 1

References

[1] David McCall, "60802 Time Sync – Should 60802 Apply Correction So TSGE Averages to Zero – v2?", 60802 contribution, Sept 2022

[2] David McCall "IEC/IEEE 60802 Contribution – Time Sync Informative Annex – v7", 60802 Contribution, Sept 2023

Content

- Constant Time Error (cTE) Budget for PTP Instances
- Normative Requirements

Error Budget

cTE Budget for PTP Instances

- Current error budget from [2]

Table 101: Time Synchronisation Error Budget

Network Aspect	Error Type	Network-Level Error Budget (ns)	Normative or Informative?
All PTP Instances	Constant Time Error	200	Normative
	Dynamic Time Error	600	
All PTP Links	Constant Time Error	200	Informative
	Dynamic Time Error	Negligible	

Note that dTE for All PTP Instances includes 50 ns from ClockSource to Application + 50 ns from ClockTarget to Application

- Constant Time Error for PTP Instances of 200 ns means…
  …2ns budget per device?

cTE at Relay Doesn't Impact Total Time Error

- From [1]…

> **Timestamp for preciseOriginTimestamp + correctionField at Grandmasters should be calibrated to average zero.**

> **802.1AS does not care about average offset TGSE for Local Clock.**
> **It does not affect dTE.**

- "…average offset TGSE for Local Clock" is the same as cTE so…

New Statement

> **802.1AS does not care about cTE for Local Clock.**
> **It does not affect dTE.**

Provided the average offset for any single node is the same for RX and TX.

- Since a PTP Relay only has a Local Clock, we don't need to budget cTE for it.

What to do with 200 ns of cTE budget?

- Proposal…
  - 10 ns for cTE of (preciseOriginTimestamp + correctionField) at Grandmaster
  - 10 ns for cTE for ClockTarget at PTP End Instance
  - 180 ns for dTE of PTP Instances
    - dTE budget for PTP Instances goes from 500 ns to 680 ns
- Other options…
  - Less budget for dTE of PTP Instances; more for cTE of PTP Links
    - Longer cable runs! (Current end-to-end limit for typical Cat6 cables is 400 m)
  - Less budget for dTE of PTP Instances; more for cTE of Grandmaster and End Instance

Normative Requirements

PTP Instance Requirements

Table 9 – Required values

Topic	Value
Local Clock, range of fractional frequency offset relative to the nominal frequency	±50 ppm
Local Clock, range of rate of change of fractional frequency offset with respect to the nominal frequency	±1 ppm/s
Working Clock (acting as ClockSource) at Grandmaster PTP Instance, range of fractional frequency offset with respect to the nominal frequency	±25 ppm
Working Clock (acting as ClockSource) at Grandmaster PTP Instance, range of rate of change of fractional frequency offset with respect to the nominal frequency (steady state, see Annex X)	±1 ppm/s
Working Clock (acting as ClockSource) at Grandmaster PTP Instance, range of rate of change of fractional frequency offset (transient, see Annex X)	±1,5 ppm/s
Working Clock at PTP End Instance, maximum value of frequency adjustment	±250 ppm over any observation interval of 1 ms
NOTE 1 If the Grandmaster PTP Instance implementation is such that its Working Clock and Local Clock are the same or otherwise locked to the same frequency, the normative requirements on the Working Clock take priority over those on the Local Clock. NOTE 2 The Maximum value of frequency adjustment represents an upper bound that limits how much a PTP End Instance can change the frequency of its Working Clock or Global Time during a given period. However, these adjustments are incremental rather than instantaneous over the defined interval.	

← Is ±1.5 ppm/s enough?

← Is this OK?

PTP Protocol Requirements – Protocol Settings – 1

Table 10 – Protocol settings

Topic	Value
Nominal time between successive Announce messages (announce interval)	1 s
Nominal time between successive Pdelay_Req messages (Pdelay_Req message transmission interval)	125 ms
Range of allowed time between successive Pdelay_Req messages	119 ms to 131 ms
Nominal time between successive Sync messages at the Grandmaster (Sync message transmission interval)	125 ms
Range of allowed time between successive Sync messages at the Grandmaster	119 ms to 131 ms
Time between reception of a Sync message and transmission of the subsequent Sync message (i.e. residence time) at a PTP Relay instance	Maximum: 15 ms Measured Mean: ≤ 5 ms

PTP Protocol Requirements – Protocol Settings – 2

Table 10 – Protocol settings

Topic	Value
Maximum time between transmission of a Sync message and transmission of the related Follow_Up message	2,5 ms
Time between reception of a Pdelay_Req message and transmission of the subsequent Pdelay_Resp message (i.e. Pdelay turnaround time).	Maximum: 15 ms Measured Mean: ≤ 5 ms
ClockTimeReceiver (servo controller)	Maximum Bandwidth (Hz): 2,6 Hz Maximum Gain Peaking (dB): 1,3 dB Minimum absolute value of Roll-off: 20 dB/decade
NOTE 1 A consequence of having a single allowed value of mean sync interval is that syncLocked mode is achieved, which is required for the desired performance. If the master port sync interval is the same as that of the slave port, syncLocked mode is achieved. NOTE 2 The values contained in this tale apply to both the Working Clock and Global Time.	

← Should this be ≥? (See [1])

← 1,5 Hz?...?

Error Generation Limits for Grandmaster

Table 11 – Error generation limits for Grandmaster PTP Instance

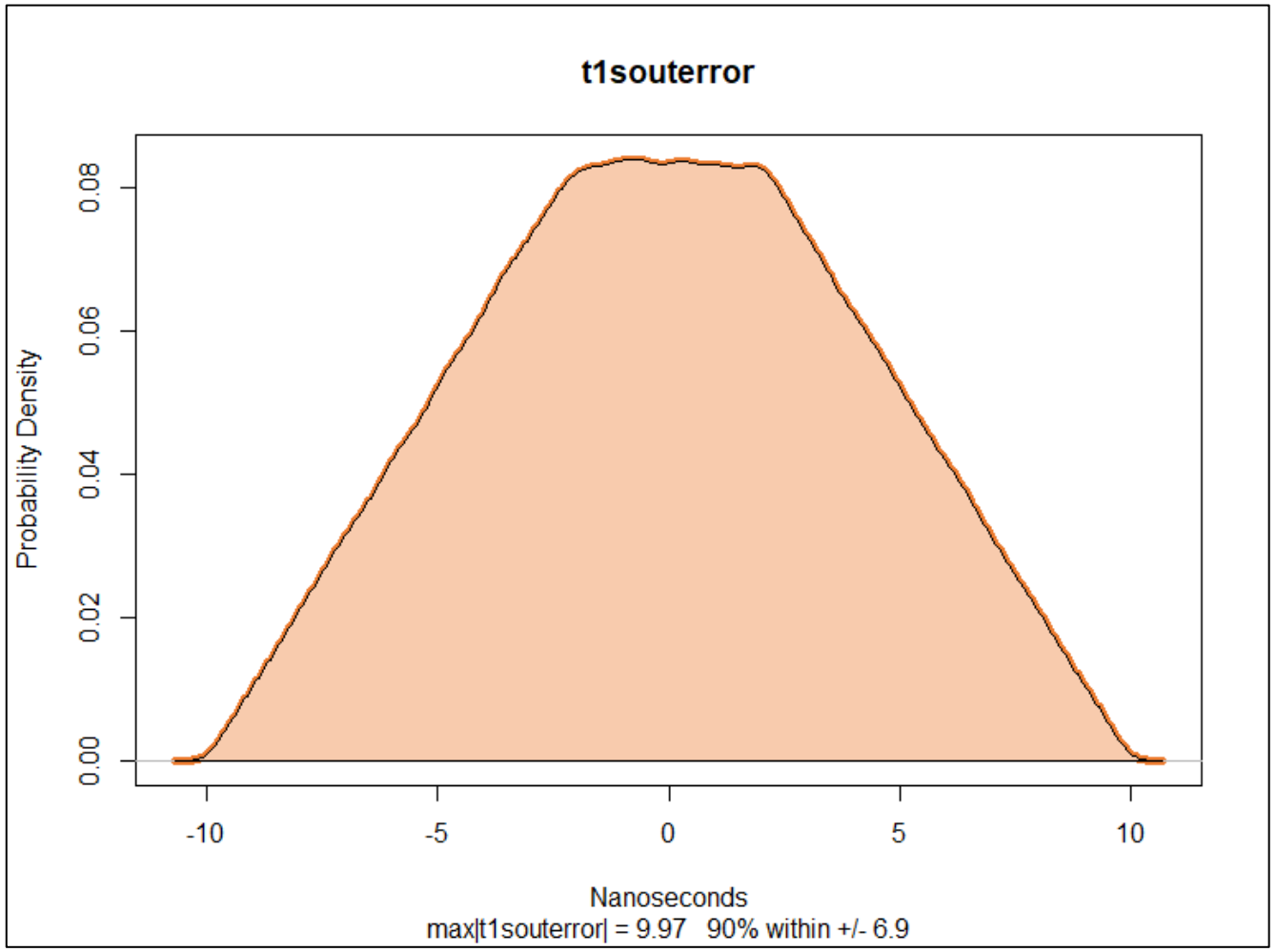
Topic	Value
(preciseOriginTimestamp + correctionField) in Sync message minus Working Clock at Grandmaster when Sync message is transmitted	Allowable range of the measured mean: 0 ns ± 10 ns Range around the measured mean within which 90% of measurements fall: ± 7 ns Maximum difference of any measurement from the measured mean: ± 10 ns
Rate Ratio between Working Clock at Grandmaster and Local Clock when Sync message is transmitted minus rateRatio field in Sync message	Mean 0 ppm ± 0,1 ppm Standard deviation ≤ 0,1 ppm
syncEgressTimestamp in Drift_Tracking TLV minus Local clock when Sync message is transmitted	Range around the measured mean within which 90% of measurements fall: ± 7 ns Maximum difference of any measurement from the measured mean: ± 10 ns

← Includes cTE. Add margin?

← Values need verification

← Does not include cTE.

Output Timestamp Error (dTE) at GM



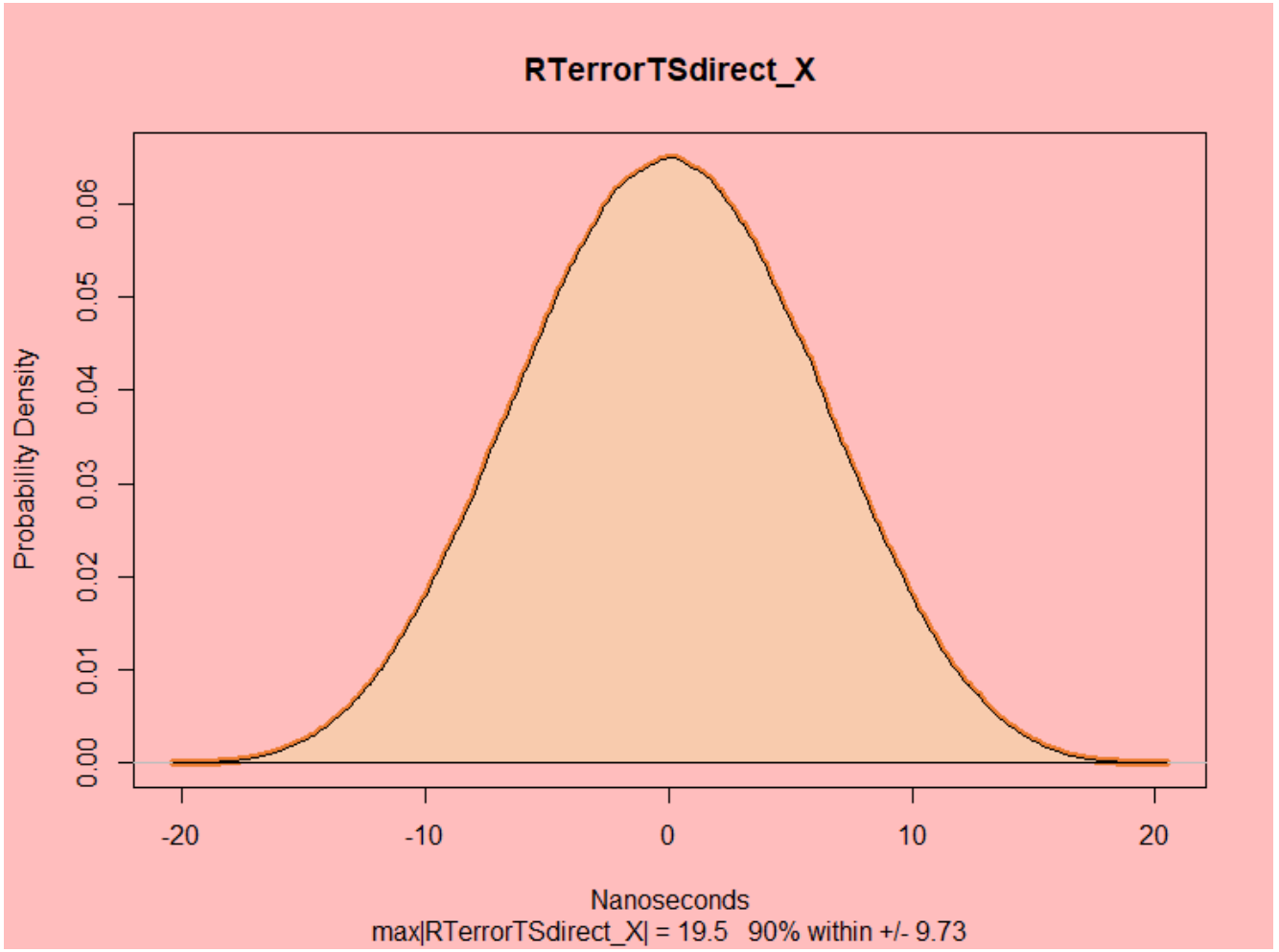
- TSGE: ±4 ns
- DTSE: ±6 ns

Error Generation Limits for PTP Relay – 1

Table 12 – Error generation limits for PTP Relay Instance

Topic	Value
(preciseOriginTimestamp + correctionField) in the Sync message transmitted by PTP Relay Instance minus Working Clock at Grandmaster when the Sync message is transmitted, while… • Working Clock at Grandmaster is stable. • Local Clock at upstream PTP Instance is stable	Range around the measured mean within which 90% of measurements fall: ± 10 ns Maximum difference of any measurement from the measured mean: ± 20 ns

residenceTime Error at PTP Relay



- TSGE: ±4 ns
- DTSE: ±6 ns

Error Generation Limits for PTP Relay – 2

Topic	Value
rateRatio field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster is stable. • Local Clock at upstream PTP Instance is stable.	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm
rateRatio field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s • Local Clock at upstream PTP Instance is stable.	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm
rateRatio field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s • Local Clock at upstream PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm

Error Generation Limits for PTP Relay – 3

Topic	Value
rateRatioDrift field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio Drift from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster is stable. • Local Clock at upstream PTP Instance is stable.	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm
rateRatioDrift field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio Drift from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s • Local Clock at upstream PTP Instance is stable.	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm
rateRatioDrift field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio Drift from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s • Local Clock at upstream PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm

Error Generation Limits for PTP Relay – 4

Topic	Value
rateRatioDrift field in the Sync message transmitted by PTP Relay Instance minus the Rate Ratio Drift from the PTP Relay Instance's Local Clock to the WorkingClock at the Grandmaster, while… • WorkingClock at Grandmaster PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s • Local Clock at upstream PTP Instance, fractional frequency offset with respect to the nominal frequency is increasing at 1 ppm/s	Measured Mean 0 ppm ± 0,1 ppm Standard Deviation around Measured Mean ≤ 0,05 ppm
syncEgressTimestamp in Drift_Tracking TLV minus Local clock when Sync message is transmitted	Range around the measured mean within which 90% of measurements fall: ± 7 ns Maximum difference of any measurement from the measured mean: ± 10 ns
NOTE 1 (preciseOriginTimestamp + correctionField) in Sync message received by PTP Relay Instance has negligible error. NOTE 2 Delay skew of connection between upstream PTP Instance and PTP Relay Instance is negligible.	

Error Generation Limits End Instance

- To be completed.

Thank you