IEC/IEEE 60802 Synchronization requirements and solution examples

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Scope

Industrial automation systems used in the areas of

- Public transportation
- Factory automation
- Process automation
- …

do have different environmental requirements.

The environmental conditions from this areas together with the device lifetime and the basic Ethernet PHY frequency quality are defining the requirements for the oscillators.

This applies to both, grandmaster and PTP end instance in this area.

1) http://www.ieee802.org/1/files/public/docs2019/60802-industrial-use-cases-0918-v13.pd

Basic Requirements

Data rate	Upper bound[2)]
10/100Mbit/s	100ppm
1Gbit/s	50ppm
>1Gbit/s	???

Lifetime[1)] > 10years

df/dt <= “Area specific”

Upper bound to F/FN <= “Link speed”

Requirements:

1) For the whole lifetime of the device under all supported environmental conditions, the frequency shall stay in the “upper bounds” and shall not change faster as stated by df/dt.

2) The sync deviation shall stay under all above stated conditions below |1µs|

	Public Transportation	Factory Automation	Process Automation	Other
df/dt	< 3ppm	< 0,3ppm	< 0,3ppm	???

1) Typical value for industrial automation. The real value depends on the product.
2) Given by IEEE802.3 MAU type requirements.

Constraints

There are a lot of sources for frequency deviation. They are all just looked at summed up for the purpose of this contribution.

Production deviation, temperature deviation, aging, voltage ripple, shock and vibration all together shall not create a frequency deviation greater than the “upper bounds” from the previous slides.

Same is valid for the speed of frequency change which shall not be greater than “df/dt” from the previous slides.

The values are not derived from measuring one oscillator – they need to be guaranteed by the oscillator vendor.

Assumption:

Worst case happens if both, the grandmaster and the end-instances are moving from the opposite endpoints of the frequency with the maximum allowed df/dt to the other endpoints, while still staying inside the +/- 100ppm f/fN limit.

Working Clock and Global Time:

The stated constraints are valid for both. The IEC/IEEE 60802 requirements for Working Clock seems only achievable with optimizations of the IEEE802.1AS model.

Contributors feedback

An in available products implemented IEEE 802.1AS model based solution using

- 31,25 ms sync interval
  [Simulation: Sync message is send every 30ms with +/- 3ms deviation]
- 1 s pdelay interval
- syncLocked mode
- Sync residence time (minimum 1ms, majority 4ms and maximum 10ms)
  [Simulation: All three should be used in the same simulation run]
- 2,5 ns Timestamp granularity
- 100 hops, linear topology with GM as first device
- Sinusoidal 3 ppm df/dt for the GM
  [Simulation: Triangular should cover the use case]
- Production, temperature, age, voltage variation, … noise df/dt for the PTP end instances
  [Simulation: Separate runs for 3ppm and “lab condition”]
- Upper bound f/fN 100 ppm

Additionally, a sliding window using the sync messages for GM rate calculation in the PTP relays/instances is implemented.

<u>Measured values </u>based on this setup

-> Sync deviation measured (at the sync out signal pins) between GM and any of the PTP instances is below |300 ns|

Basic timer model

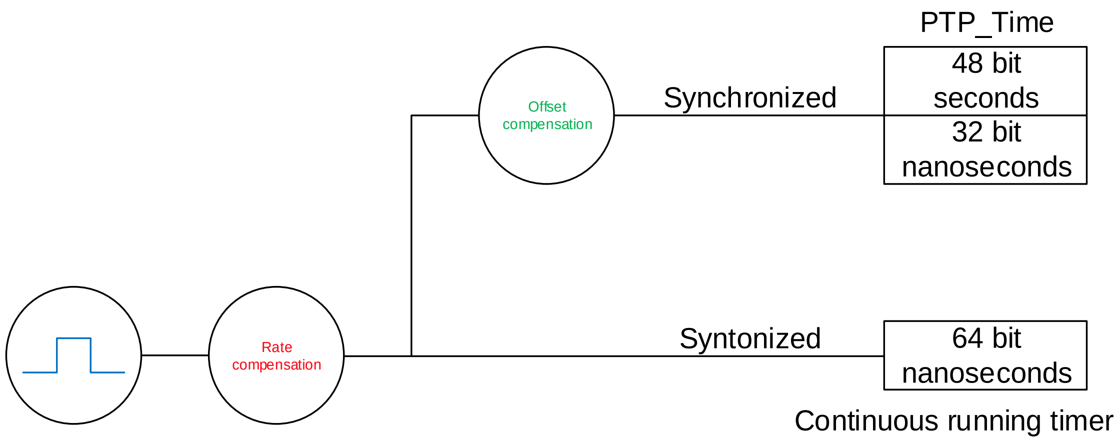
The used timer model of this contribution is build as shown in the figure on this slide.

The rate compensated frequency (rate to the GM) is used for the 64 bit continuous running timer and as basis for the PTP time of the PTP end instance.

-> 64 bit continuous running timer
used to rate compensate residence time

The offset correction is done by an additional rate compensation for the PTP end instance time.

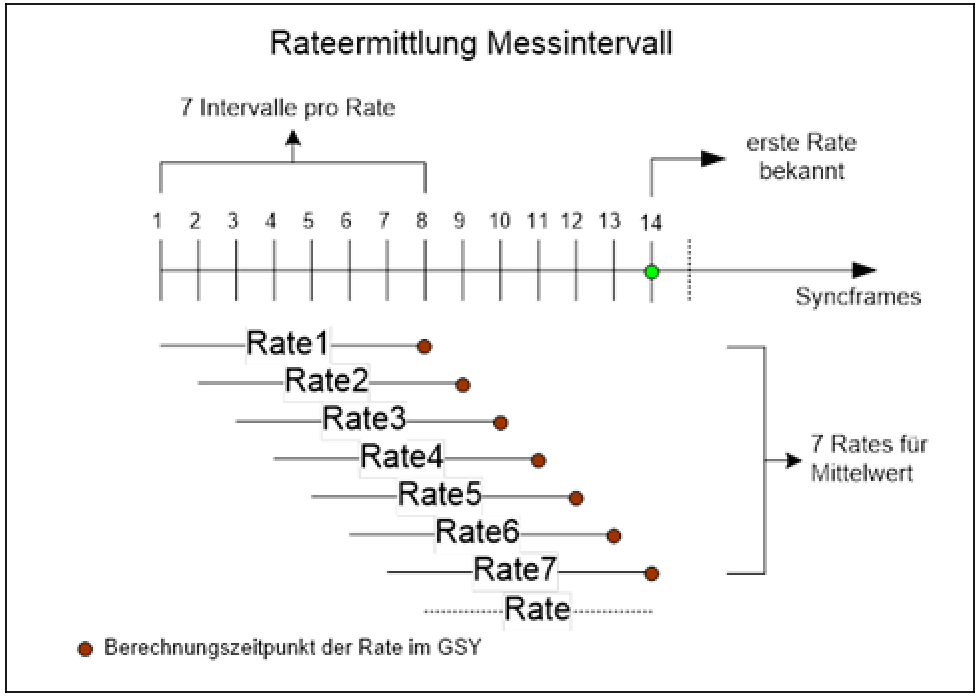
-> used for PTP time



PTP relay model

The PTP relay uses the sliding window (window size seven sync messages (210ms)) calculated and filtered (median over the last seven calculated values) rate to the GM for the residence time of the sync message.

Editors note: Median and not arithmetic mean is used.



PTP end instance model

	Maximum Offset correction factor	Kp/Ki
Working Clock	< 250ppm	11/65
Global Time	< 250ppm	11/20

The PTP end instance uses the same model as the PTP relay to calculate the rate.

Additionally, the offset between the GM and the end instance time is calculated and a offset correction factor calculated.

Rate = Frequency deviation between GM and PTP end instance
Offset correction factor = Correction (faster/slower) of the frequency used for the PTP end instance time.

The Offset correction factor is calculated by the PI filter of the PTP end instance to minimize the offset between GM and PTP end instance.
The correction speed (maximum Offset correction factor) is limited due to the application timing requirements. Otherwise, local time intervals would get “to small” or “to large”.

New rate(PTP end instance time) = Oscillator + Rate + Offset correction factor
Is used to drive the PTP end instance timescale.

Both, Rate and Offset correction factor are calculated (PI controller with Kp/Ki) and updated with every received sync frame following the stated model.

Questions?