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

Packet over Transport aspects – Synchronization, quality
and availability targets

**SERIES Y: GLOBAL INFORMATION
INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS,
NEXT-GENERATION NETWORKS, INTERNET OF
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Internet protocol aspects – Transport

Timing characteristics of packet-based equipment clocks

Recommendation ITU-T G.8263/Y.1363

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Recommendation ITU-T G.8263/Y.1363

Timing characteristics of packet-based equipment clocks

Summary

Recommendation ITU-T G.8263/Y.1363 outlines requirements for timing devices used in synchronizing network equipment that operates in the interworking function (IWF) and other network elements (NEs) as defined in Recommendation ITU-T G.8261/Y.1361. Recommendation ITU-T G.8263/Y.1363 defines the requirements for packet-based equipment clocks.

History

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Clock, jitter, synchronization, wander.

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FOREWORD

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Recommendation ITU-T G.8263/Y.1363

Timing characteristics of packet-based equipment clocks

1 Scope

This Recommendation outlines minimum requirements for the timing functions of the packet slave clocks as defined in [ITU-T G.8265]. It supports frequency synchronization distribution when using packet-based methods.

This Recommendation allows for proper network operation when a packet slave clock is timed from a packet master clock as defined in [ITU-T G.8265].

This Recommendation focuses on mobile applications, and in particular on the delivery of frequency synchronization for end applications, such as mobile base stations. It supports the architecture defined in [ITU-T G.8265]. Other applications are for further study.

This Recommendation focuses on two different deployment cases for the packet slave clock as follows.

- Packet slave clock embedded in a device co-located with the end application, as shown after the connection C1 in Figure 3 of [ITU-T G.8261.1].
- Packet slave clock embedded within the end application, as shown after the connection C2 in Figure 3 of [ITU-T G.8261.1]. This second case is for further study for the first version of this Recommendation.

Other deployment cases for the packet slave clock are for further study.

This Recommendation focuses on the types of networks corresponding to the hypothetical reference models, HRM-1 and HRM-2, defined in [ITU-T G.8261.1].

NOTE – For long observation intervals, the packet-based equipment clock – slave – frequency (PEC-S-F) is expected to compensate for temperature variation effects; therefore, the output of the PEC-S-F will converge to the 1 ppb slope.

The HRM-2 type of network is for further study for the first version of this Recommendation. Other types of networks are outside the scope of this Recommendation.

This Recommendation defines the minimum requirements for the packet slave clocks. These requirements apply under the normal environmental conditions specified for the equipment.

This Recommendation includes clock accuracy, packet delay variation (PDV) noise tolerance, holdover performance and noise generation. The start-up conditions (e.g., variable filtering bandwidth at start-up and stabilization period) are for further study.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.703] Recommendation ITU-T G.703 (2016), *Physical/electrical characteristics of hierarchical digital interfaces*.

- [ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks.*
- [ITU-T G.811] Recommendation ITU-T G.811 (1997), *Timing characteristics of primary reference clocks.*
- [ITU-T G.823] Recommendation ITU-T G.823 (2000), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy.*
- [ITU-T G.824] Recommendation ITU-T G.824 (2000), *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy.*
- [ITU-T G.8260] Recommendation ITU-T G.8260 (2015), *Definitions and terminology for synchronization in packet networks.*
- [ITU-T G.8261] Recommendation ITU-T G.8261/Y.1361 (2008), *Timing and synchronization aspects in packet networks.*
- [ITU-T G.8261.1] Recommendation ITU-T G.8261.1/Y.1361.1 (2012), *Packet delay variation network limits applicable to packet-based methods (Frequency synchronization).*
- [ITU-T G.8265] Recommendation ITU-T G.8265/Y.1365 (2010), *Architecture and requirements for packet-based frequency delivery.*
- [ITU-T G.8265.1] Recommendation ITU-T G.8265.1/Y.1365.1 (2014), *Precision time protocol telecom profile for frequency synchronization.*

3 Definitions

Definitions related to synchronization are contained in [ITU-T G.810] and [ITU-T G.8260].

4 Abbreviations and acronyms

For the purposes of this Recommendation, the following abbreviations and acronyms are used:

CBR	Constant Bit Rate
CES	Circuit Emulation Service
CUT	Clock Under Test
EEC	synchronous Ethernet Equipment Clock
FPP	Floor Packet Percentageool
FR	Frequency Reference
GM	Grandmaster
HRM	Hypothetical Reference Model
IWF	Interworking Function
MAFE	Maximum Average Frequency Error
MTIE	Maximum Time Interval Error
NE	Network Element
PDV	Packet Delay Variation
PEC-M	Packet-based Equipment Clock – Master
PEC-S	Packet-based Equipment Clock – Slave

PEC-S-F	Packet-based Equipment Clock – Slave – Frequency
PHY	Physical (layer)
PRC	Primary Reference Clock
PSD	Power Spectral Density
PTP	Precision Time Protocol
PTS	Packet Timing Signal
PTSF	Packet Timing Signal Fail
SEC	Synchronous digital hierarchy Equipment Clock
SSM	Synchronization Status Message
TDEV	Time Deviation

5 Frequency accuracy

5.1 Packet-based equipment clock – slave – frequency

Under free running conditions, the output frequency accuracy of the PEC-S-F should not be greater than 4.6 ppm with regard to a reference traceable to an ITU-T G.811 clock.

NOTE – The time interval for this accuracy is for further study. Values of 1 month and 1 year have been proposed.

6 Noise generation

The noise generation of a packet-based equipment clock – slave (PEC-S) represents the amount of phase noise produced at the output of the PEC-S when there is an ideal input reference packet timing signal (PTS). Figure 1 illustrates the testing procedure:

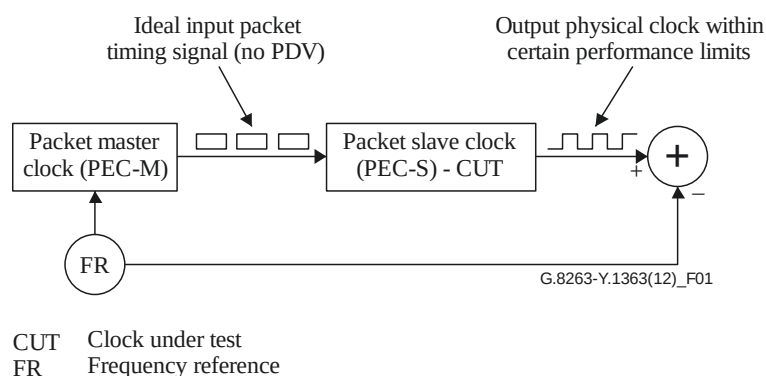


Figure 1 – Noise generation testing procedure

It should be noted that packet-based equipment clocks – slave – frequency according to the architecture defined in [ITU-T G.8265] (see Figure 1 of [ITU-T G.8265]) are not cascaded; therefore, specification of noise generation produced at the output of the clock is not required when there is an ideal input reference signal. In fact, the applicable noise generation requirement is already covered by the specifications provided in clause 7 of this Recommendation. However, this specification is provided in order to enable network operators to measure the noise produced by the PEC-S-F under ideal conditions, separately from the scenarios where PDV is applied (PDV noise tolerance testing).

The maximum time interval error (MTIE) is measured through an equivalent 10 Hz, first-order, low-pass measurement filter, at a maximum sampling time of 1/30 s.

6.1 Packet-based equipment clock – slave – frequency

When the PEC-S-F is in the locked mode of operation, synchronized to a PDV free reference, and its MTIE output is measured using the same reference as the packet master clock which generated the PTS, the MTIE should have the limits described in Table 1, if the temperature is constant (within ± 1 K).

Table 1 – Wander generation (maximum time interval error) for packet-based equipment clock – slave – frequency with constant temperature

MTIE limit (ns)	Observation interval τ (s)
1 000	$0.1 < \tau \leq 1000$
τ	$\tau > 1\,000$ (Note)
NOTE – The maximum applicable observation interval is for further study.	

The resultant requirement is shown by the solid line in Figure 2.

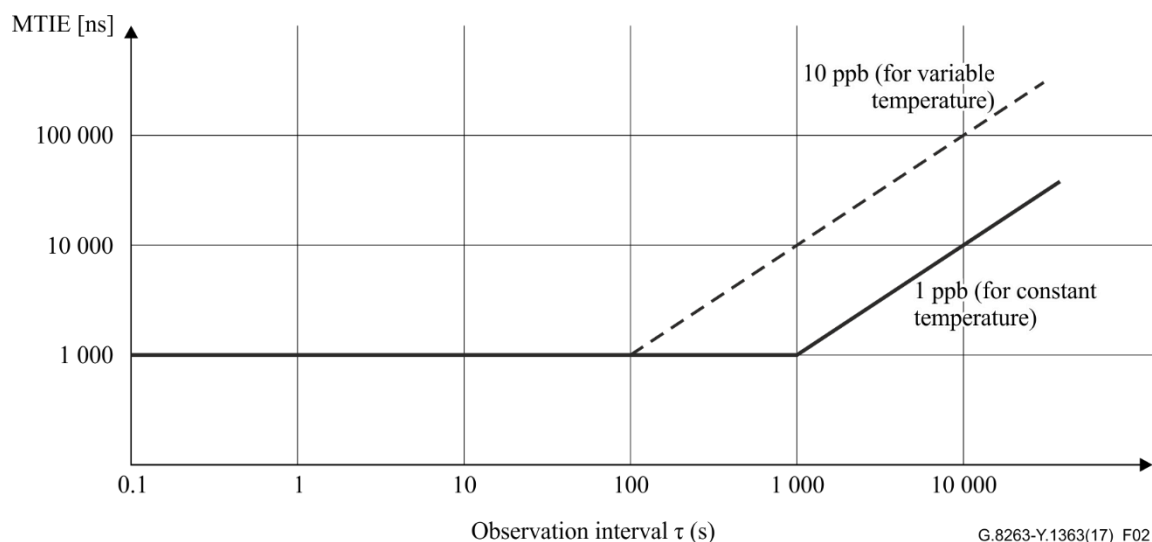


Figure 2 – Wander generation (maximum time interval error) for packet-based equipment clock – slave – frequency

NOTE – For long observation intervals, the PEC-S-F is expected to compensate for temperature variation effects; therefore, the output of the PEC-S-F will converge to the 1 ns/s slope.

When temperature effects are included, the limits are given in Table 2.

Table 2 – Wander generation (maximum time interval error) for packet-based equipment clock – slave – frequency with temperature effects

Additional MTIE allowance (ns)	Observation interval τ (s)
1000	$0.1 < \tau \leq 100$
$10\,\tau$	$\tau > 100$ (Note)
NOTE 1 – The maximum applicable observation interval is for further study.	
NOTE 2 – When testing under the worst case temperature variation and depending on the time constant of the loop, the ageing characteristics of the oscillator may add an additional noise at the output of PEC-S-F that may slightly exceed the variable temperature mask.	

The resultant requirements are shown by the dashed line in Figure 2.

7 Packet delay variation noise tolerance

7.1 Packet-based equipment clock – slave – frequency

The PDV noise tolerance of the PEC-S-F indicates the minimum PDV noise at the input of the PEC-S-F. It indicates the noise at the PTS that the PEC-S-F must tolerate.

The model for a packet slave clock is shown in Figure A.1. The transfer characteristics of PEC-S-F determines its property with regard to the filtering of PDV noise at the PTS and generates a clock frequency traceable to the input timing signal available at the packet master clock.

The PEC-S-F must tolerate the noise at the limits specified in clause 8.1.1 of [ITU-T G.8261.1] (PDV network limits at point C). Under these conditions, the output clock of the PEC-S-F must:

- not cause the packet timing signal fail- (PTSF-) unusable signal to be triggered (this is for further study);
- not cause the clock to go into holdover;
- maintain the clock within the following prescribed performance limits, depending on the applicable use case:
 - the limits defined for case 3 in clause 7.2.2 of [ITU-T G.8261.1], as defined in reference point D in Figure 3 of [ITU-T G.8261.1], where $n = 16$ ppb as shown in Table 1 of [ITU-T G.8261.1] and Figure 4 of [ITU-T G.8261.1],
 - the limits defined for case 2 in clause 7.2.2 of [ITU-T G.8261.1], as defined in reference point D in Figure 3 of [ITU-T G.8261.1] – this case is for further study.

NOTE 1 – The above limits apply to a PEC-S-F external to the end application (point C1 in Figure 3 of [ITU-T G.8261.1]). The limits corresponding to the end application at the point E in Figure 3 of [ITU-T G.8261.1] for the case of a PEC-S-F embedded in the end application (point C2 in Figure 3 of [ITU-T G.8261.1]) are for further study.

NOTE 2 – For the particular packet rate used by an actual PEC-S-F implementation, within the range specified in [ITU-T G.8265.1], the clock must tolerate the PDV generated by the network as specified in [ITU-T G.8261.1]. More specifically, for HRM-1 of [ITU-T G.8261.1], the PEC-S-F must also meet the output performance specification for its particular packet rate when only 1% of the timing packets sent by the packet master remain in the 150 μ s fixed cluster range, starting at the floor delay in every observation window of 200 s.

NOTE 3 – The way to generate a PTS (PDV pattern) experiencing noise at the limits specified in clause 8 of [ITU-T G.8261.1] is for further study. For the purpose of PDV input tolerance testing, the maximum duration of the test period is for further study. Possible testing methodologies for HRM-1 of [ITU-T G.8261.1] are given in Appendix I.

NOTE 4 – As described in clause 8.1.2 of [ITU-T G.8261.1], many networks may exhibit lower PDV compared with the network limit for HRM-1 specified in clause 8.1.1 of [ITU-T G.8261.1]. This Recommendation defines one type of packet slave clock that is suitable for use with HRM-1, as described in clause 8.1.1 of [ITU-T G.8261.1]. Some operators may decide to use a different type of packet slave clock if their network limits comply with clause 8.1.2 of [ITU-T G.8261.1]; this alternate type of packet slave clock is for further study.

8 Long-term phase transient response (holdover)

When a PEC-S clock loses all its references, it enters the holdover state. This clause describes the behaviour required of the PEC-S clock during this state.

NOTE – This specification for holdover assumes that an ideal input was applied to the PEC-S-F before entering holdover.