International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.8261.1/Y.1361.1

(02/2012)

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Packet delay variation network limits applicable to packet-based methods (Frequency synchronization)

Recommendation ITU-T G.8261.1/Y.1361.1

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Recommendation ITU-T G.8261.1/Y.1361.1

Packet delay variation network limits applicable to packet-based methods (Frequency synchronization)

Summary

Recommendation ITU-T G.8261.1/Y.1361.1 depicts synchronization aspects in packet networks. In particular, it specifies the hypothetical reference model and the PDV network limits applicable when frequency synchronization is carried via packets and is recovered according to an adaptive clock recovery method as defined in Recommendations ITU-T G.8261 and ITU-T G.8260. It specifies the minimum equipment tolerance to packet delay variation in terms of the metrics defined in Recommendation ITU-T G.8260 at the boundary of these packet networks.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.8261.1/Y.1361.1	2012-02-13	15

Keywords

PDV, synchronization.

FOREWORD

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Recommendation ITU-T G.8261.1/Y.1361.1

Packet delay variation network limits applicable to packet-based methods (Frequency synchronization)

1 Scope

This Recommendation relays synchronization aspects in packet networks. In particular, it specifies the hypothetical reference model (HRM) and the PDV network limits applicable when frequency synchronization is carried via packets and is recovered according to the adaptive clock recovery method as defined in Recommendations ITU-T G.8261 and ITU-T G.8260. It specifies the minimum equipment tolerance to packet delay variation in terms of the metrics defined in Recommendation ITU-T G.8260 at the boundary of these packet networks.

Two main applications are addressed in this Recommendation: the distribution of a synchronization network clock signal via a packet based method (e.g., using PTP or NTP packets and using an adaptive approach), and the distribution of a service clock signal over a packet network according to an adaptive clock recovery method (e.g., clock recovery of a circuit emulation service (CES) using an adaptive method), however the details on the CES network limits are for further study.

Both one-way and two-way methods are considered.

The packet networks that are in the scope of this Recommendation are currently limited to the following scenarios:

- Ethernet ([IEEE 802.3], [IEEE 802.1D], [IEEE 802.1 ad], [IEEE 802.1Q], [IEEE 802.1Qay])
- MPLS ([IETF RFC 3031], [ITU-T G.8110])
- IP ([IETF RFC 791] and [IETF RFC 2460])

The physical layer that is relevant to this specification is the Ethernet media types as defined in IEEE Standard 802.3 ™–2008. Other physical layers can be relevant and may be addressed in future versions of this Recommendation.

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.803] Recommendation ITU-T G.803 (2000), *Architecture of transport networks based on the synchronous digital hierarchy (SDH)*.

[ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks*.

[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.8110] Recommendation ITU-T G.8110/Y.1370 (2005), *MPLS layer network architecture*.

[ITU-T G.8260] Recommendation ITU-T G.8260 (2012), *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.8263] Recommendation ITU-T G.8263/Y.1363 (2012), *Timing characteristics of packet-based equipment clocks*.

[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 (2010), *Precision time protocol telecom profile for frequency synchronization*.

[ITU-T O.172] Recommendation ITU-T O.172 (2005), *Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH)*.

[IEEE 802] IEEE 802-2001, *IEEE standard for local and metropolitan area networks: Overview and architecture.* <http://standards.ieee.org/getieee802/802.html>

[IEEE 802.1ad] IEEE 802.1ad™-2005, *IEEE Standard for local and metropolitan area networks: Virtual bridged local area networks – Amendment 4: Provider Bridges*. <http://standards.ieee.org/getieee802/download/802.1ad-2005.pdf>

[IEEE 802.1D] IEEE 802.1D™-2004, *IEEE Standard for local and metropolitan area networks: Media Access Control (MAC) Bridges*. <http://standards.ieee.org/getieee802/download/802.1D-2004.pdf>

[IEEE 802.1Q] IEEE 802.1Q™-2005, *IEEE Standard for local and metropolitan area networks: Virtual bridged local area networks*. <http://standards.ieee.org/getieee802/download/802.1Q-2005.pdf>

[IEEE 802.3] IEEE 802.3-2008, *Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*. <http://standards.ieee.org/getieee802/802.3.html>

[IETF RFC 791] IETF RFC 791 (1981), *Internet Protocol.* <http://www.ietf.org/rfc/rfc0791.txt?number=791>

[IETF RFC 2460] IETF RFC 2460 (1998), *Internet Protocol, Version 6 (IPv6) Specification*. <http://www.ietf.org/rfc/rfc2460.txt?number=2460>

[IETF RFC 3031] IETF RFC 3031 (2001), *Multiprotocol Label Switching Architecture*. <http://www.ietf.org/rfc/rfc3031.txt?number=3031>

3 Definitions

The terms and definitions used in this Recommendation are found in [ITU-T G.810] and [ITU-T G.8260].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CES Circuit Emulation Service

DSL Digital Subscriber Line

DSLAM	Digital Subscriber Line Access Multiplexer
EEC	Ethernet Equipment Clock
HRM	Hypothetical Reference Model
MW	Microwave
OLT	Optical Line Terminal
ONU	Optical Network Unit
OTN	Optical Transport Network
PDV	Packet Delay Variation
PEC-M	Packet-based Equipment Clock Master
PEC-S-F	Packet based Equipment Clock Slave Frequency
PNT-F	Packet Network Timing Function
PON	Passive Optical Network
PRC	Primary Reference Clock
PTP	Precision Time Protocol
SEC	SDH Equipment Clock
SSU	Synchronization Supply Unit

5 Conventions

None.

6 General

The use of packet-based methods as described in [ITU-T G.8261] to deliver reference timing signals for the purpose of frequency synchronization, requires the control of the PDV generated in the network in order to meet acceptable performance requirements when using a packet clock with characteristics as specified in [ITU-T G.8263].

This Recommendation defines the applicable network limits at all relevant points in a network.

The network reference models and the related target performance requirements that are considered relevant for this application are described in clause 7. The related PDV limits are specified in clause 8.

7 Network reference model

7.1 Hypothetical reference models

This clause provides hypothetical reference models which are assumed to correspond to the worst-case models for most of the mobile backhaul networks.

NOTE – The hypothetical reference models defined in this clause are assumed to be composed with network equipment generating a controlled amount of PDV, compatible with the network limits defined in clause 8. It is known that some network equipment may generate excessive PDV, leading potentially to exceed these PDV network limits. What constitutes a controlled amount of PDV, how to determine if particular network equipment are suitable for being considered in these hypothetical reference models, or in a reduced hypothetical reference model, as well as, how to evaluate the level of PDV generated by a network equipment, is for further study.

7.1.1 HRM-1: network using only 1 Gbit/s and 10 Gbit/s connections

The HRM-1 is shown in Figure 1 below; it is composed of a 1 Gbit/s link to connect the packet master clock to the first node, 3 × 10 Gbit/s fibre optical links and 7 × 1 Gbit/s fibre optical links. It is assumed to correspond to the worst case model for most of the mobile backhaul networks using only optical fibre connections.

The packet delay variation network limits for the HRM-1 are specified in clause 8 of this Recommendation.

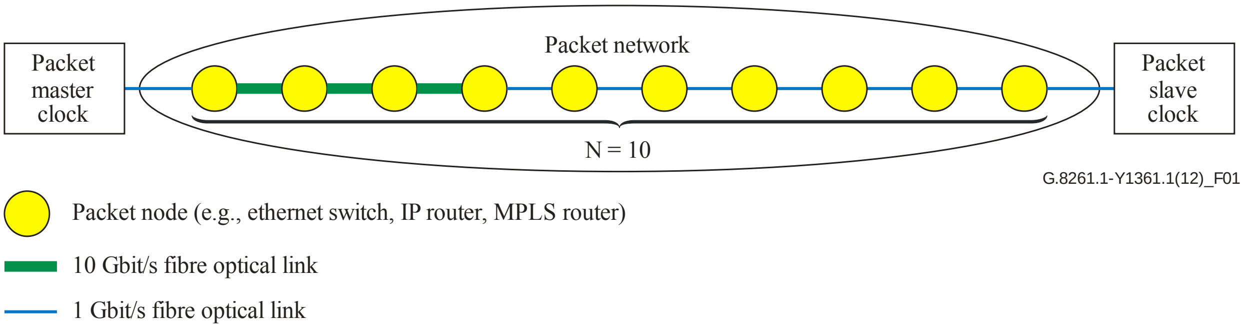

Figure 1 – HRM-1 for packet delay variation network limits

NOTE 1 – The link between the packet master clock and the first packet node may be 100 Mbit/s instead of 1 Gbit/s.

NOTE 2 – The link between the last packet node and the packet slave clock may be 100 Mbit/s instead of 1 Gbit/s in case it is only carrying PTPv2 messages and no data traffic.

NOTE 3 – The 1 Gbit/s links can be replaced by 10 Gbit/s links in a real deployment, but not the opposite.

NOTE 4 – The distribution of the links connecting the packet nodes has no importance (e.g., the 10 Gbit/s links may not always be at the beginning of the packet network); in general however, the 10 Gbit/s links are located in the core network.

NOTE 5 – Some of the links connecting the packet nodes may be carried over an OTN network, assuming that the PDV generated by these transmission techniques is negligible compared to the PDV generated by the packet nodes of the HRM.

Some of the links connecting the packet nodes may also be carried over an SDH network, this is for further study.

NOTE 6 – It is assumed that no frames larger than 2000 bytes are carried over the links of the packet network carrying the PTPv2 messages.

NOTE 7 – The PTPv2 messages are assumed to be carried with the highest priority, and placed in a strict priority queue in the packet nodes; the other flows using this queue are for further study (it might be assumed that this queue either only contains PTPv2 messages, or that the other data traffic packets going also in this queue are small packets, and that the amount of data in the queue is much smaller than the output interface capacity).

NOTE 8 – The traffic models carried over this network are for further study; they may include both mobile and fixed data traffic.

7.1.2 HRM-2: network using specific access technologies

In many mobile backhaul networks, a base station is connected to the network using specific access technologies, such as digital subscriber line (DSL), passive optical network (PON), or microwave links (MW).

The HRM-2 is shown in Figure 2 below; it is composed of a reduced HRM-1 (1 Gbit/s link to connect the packet master clock to the first node, 1 × 10 Gbit/s fibre optical link and 4 × 1 Gbit/s fibre optical links), followed by either a DSL link (HRM-2a), or a PON link (HRM-2b), or a few MW links (HRM-2c), followed by a 1 Gbit/s link to connect the access portion to the packet slave clock. It is assumed to correspond to the worst case model for most of the mobile backhaul networks using specific access technologies.

The packet delay variation network limits for the HRM-2 are specified in clause 8 of this Recommendation.

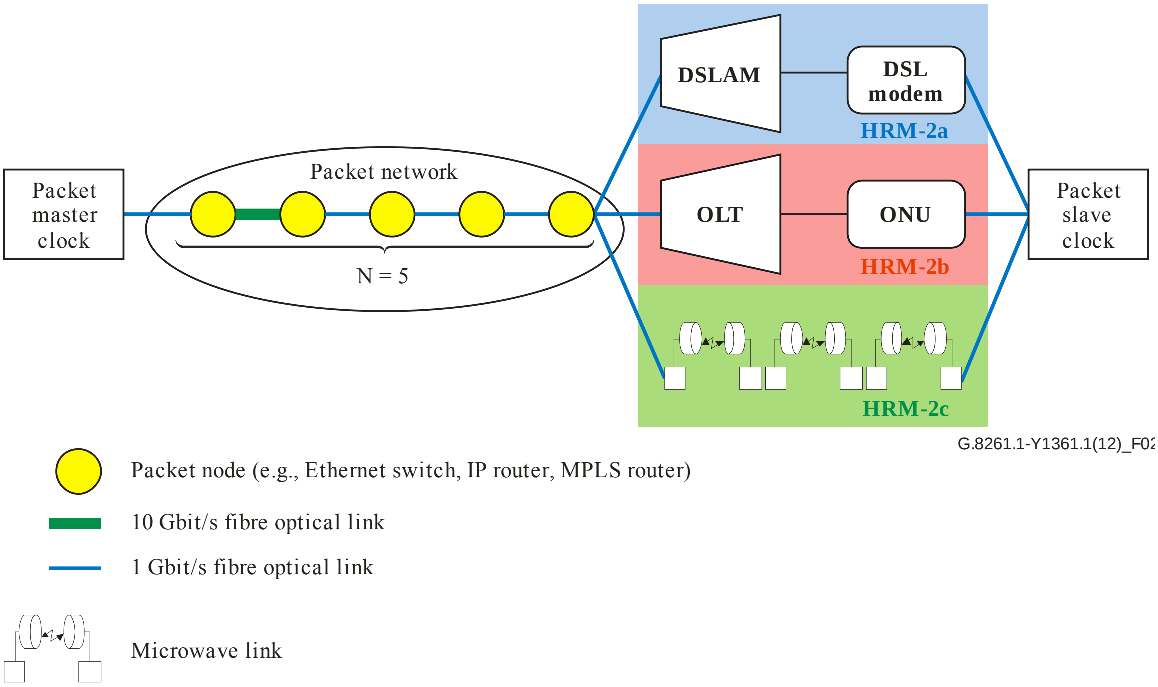

Figure 2 – HRM-2 for packet delay variation network limits

NOTE 1 – The link between the packet master clock and the first packet node may be 100 Mbit/s instead of 1 Gbit/s.

NOTE 2 – The link between the last access node and the packet slave clock may be 100 Mbit/s instead of 1 Gbit/s in case it is only carrying PTPv2 messages and no data traffic.

NOTE 3 – The 1 Gbit/s links can be replaced by 10 Gbit/s links in a real deployment, but not the opposite.

NOTE 4 – The distribution of the links connecting the packet nodes has no importance (e.g., the 10 Gbit/s link may not always be at the beginning of the packet network); in general however, the 10 Gbit/s links are located in the core network.

NOTE 5 – Some of the links connecting the packet nodes may be carried over an OTN network, assuming that the PDV generated by these transmission techniques is negligible compared to the PDV generated by the packet nodes of the HRM.

Some of the links connecting the packet nodes may also be carried over an SDH network, this is for further study.

NOTE 6 – It is assumed that no frames larger than 2000 bytes are carried over the links of the packet network carrying the PTPv2 messages.

NOTE 7 – The PTPv2 messages are assumed to be carried with the highest priority, and placed in a strict priority queue in the packet nodes and in the access equipment; the other flows using this queue are for further study (it might be assumed that this queue either only contains PTPv2 messages, or that the other data traffic packets going also in this queue are small packets, and that the amount of data in the queue is much smaller than the output interface capacity).

NOTE 8 – The traffic models carried over this network are for further study; they may include both mobile and fixed data traffic.

NOTE 9 – The DSL technologies in the HRM-2a to be considered are SHDSL and VDSL2; the PDV noise generated by these technologies is for further study, and may differ significantly from other technologies.

NOTE 10 – The HRM-2c may involve adaptive microwave equipment, adapting their bandwidth to the weather conditions.

NOTE 11 – The number of microwave hops in the HRM-2c is for further study.

NOTE 12 – The bandwidth of the links connecting the DSLAM to the modem in the HRM-2a, the OLT to the ONU in the HRM-2b, and two microwave sites in the HRM-2c is for further study.

NOTE 13 – The traffic carried over the microwave links in the HRM-2c is for further study (microwave links may aggregate traffic coming from other sites than the packet slave clock site).

7.2 Reference points for network limits in packet networks

Figure 3 shows all the network limits reference points applicable to a generalization of the PNT deployment case 2 as shown in Figure 18 of [ITU-T G.8261] (e.g., between the PRC and the packet master clock, the timing reference signal is distributed via a physical layer based synchronization network).

The use case described by PNT deployment case 1 as shown in Figure 17 of [ITU-T G.8261] where the PEC-S-F provides an external synchronization interface to the connected synchronization network is for further study.

Details on the CES network limits are also for further study.

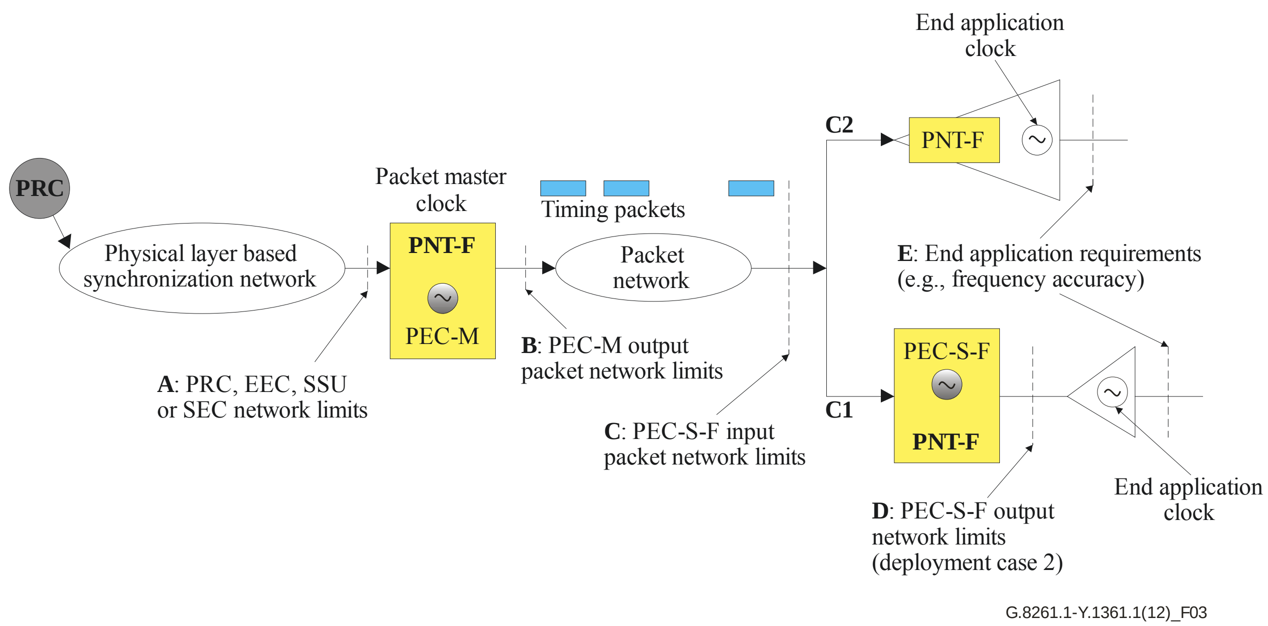

Figure 3 – Reference points for network limits

7.2.1 Packet master clock (PEC-M) network limits

This clause addresses the case of the PEC-M network limits.

In this case the network limits are applicable at the input of the PEC-M (interface A). Depending on the details of the synchronization network connected to the PEC-M, these are:

- EEC network limits (in case of a synchronous Ethernet), see clause 9.2.1 of [ITU-T G.8261]
- SEC/SSU network limits (in case of an SDH based synchronization network), see clauses 6.2.2 and 6.2.3 of [ITU-T G.823]
- the PRC interface limits (in case a PRC is directly connected to the PEC), see clause 6.2.1 of [ITU-T G.823].

The most general case that is considered in this Recommendation is when the reference timing signal is distributed to the PEC-M via a full synchronization network reference chain as described in Figure 8-5 of [ITU-T G.803] (note that the PEC-M clock itself must be considered as part of the chain), see [ITU-T G.803]. Therefore the EEC or SEC network limits as defined in clauses 9.2.1 of [ITU-T G.8261] and 6.2.3 of [ITU-T G.823], respectively, are considered.

The packet network limits at the output of the PEC-M (reference point B in Figure 3) are defined on the packet timing signal in terms of the relevant metric. This is for further study.

NOTE 1 – The PDV at the output of the packet master clock is expected to be relatively low, that means that the metric to be used in this case does not need to include particular packet pre-processing (e.g., packet selection).

NOTE 2 – The PEC-M can also be modelled by the PEC included in the PNT-F (see Figure B.5 of [ITU-T G.8261]; Note 1) where the PNT-F translates the timing carrier from the physical layer to the packet layer.

7.2.2 PEC-S-F network limits

This section addresses the case of the PEC-S-F network limits.

With reference to Figure 3, over the C1 connection, the PEC-S-F provides an external synchronization interface to the end application (i.e., PNT deployment case 2 shown in Figure 18 of [ITU-T G.8261).

In these cases, the network limits are specified by [ITU-T G.8261] (clause 9.2.2) on the recovered reference timing signal.

In particular as described in clause 9.2.2 and Appendix IV of [ITU-T G.8261], the following three main cases can be identified for the network limits applicable at interface D:

- Case 1: EEC network limits (see clause 9.2.2.1 of [ITU-T G.8261]). This case is for further study.
- Case 2: network limits for traffic interfaces (see clause 5 of [ITU-T G.823] or clause 5 of [ITU-T G.824]).
- Case 3: limits on the short term are set by [ITU-T G.823] and [ITU-T G.824] clause 5 and on the long term by an *n* ppb line (where *n* shall be below the applicable requirement on the radio interface).

With respect to case 3, and assuming $n = 16$ ppb, the output wander network limit applicable at reference point D is provided by Table 1 and Figure 4.

NOTE – The equivalent mask in case of ITU-T G.824 is for further study.

Table 1 – Output wander network limit for case 3 based on [ITU-T G.823]

Observation interval τ (s)	MTIE requirement (μs)
0.05 < τ ≤ 0.2	46 τ
0.2 < τ ≤ 32	9
32 < τ ≤ 64	0.28 τ
64 < τ ≤ 1 125	18
τ > 1 125	0.016 τ

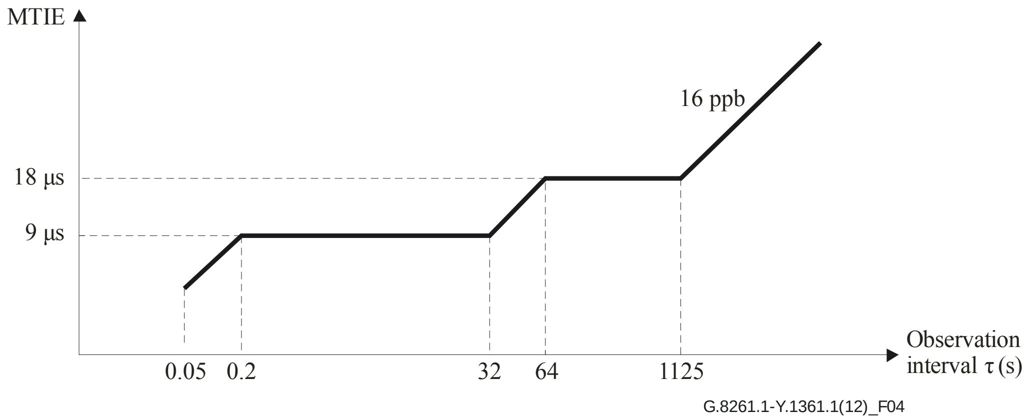

Figure 4 – Output wander network limit for case 3 based on [ITU-T G.823]

The wander measurement requirements (e.g., sampling time and measurement interval) for the MTIE parameters, the 10 Hz wander measurement filter characteristic and the functional description for measuring output wander are described in [ITU-T O.172]. Instrumentation in accordance with [ITU-T O.172] is appropriate for measurement of wander parameters.

The packet network limits are expressed in terms of the relevant PDV based metric at interface C (in fact in this case the timing recovery is based on the adaptive method) as defined in clause 8 of this Recommendation.

The connection over C2 in Figure 3 describes the case when the PNT-F and the related PEC-S-F are integrated in the end application.

In this case, the packet network interface (e.g., Ethernet interface) is directly connected to the end application (e.g., base station with Ethernet interface) and the network limits can only be expressed at the interface C. In fact, the PNT-F output (the equivalent of the interface D of the connection C1 in Figure 3) is not generally accessible for measurement for the connection over C2.

The network limits at the output of the end equipment depends on the end application requirement (reference point E). This is for further study.

8 PDV network limit

The packet delay variation network limit given in this clause represents the maximum permissible levels of packet delay variation at the interface C shown in Figure 3.

The limits given in this section shall be met for all operating conditions. In general, these network limits are compatible with the minimum tolerance to packet delay variation that all PEC-S-F equipment are required to provide.

NOTE – The PEC embedded within the end application, as shown after the connection C2 in Figure 3 is for further study in [ITU-T G.8263].

Note that the PDV network limit specified in this clause assumes that the network equipment composing the hypothetical reference model generates a controlled amount of PDV. It is known that some network equipment may generate excessive PDV and potentially exceed these PDV network limits. What constitutes a controlled amount of PDV, how to determine if network equipment is suitable for being considered in the hypothetical reference models defined in this Recommendation, or in a reduced hypothetical reference model, as well as how to evaluate the level of PDV generated by network equipment, is for further study.

The packet delay variation network limit at point C of Figure 3 for the HRM-1 shown in Figure 1 is defined as follows:

With window interval $W = 200$ s and fixed cluster range $\delta = 150$ µs starting at the floor delay, the network transfer characteristic quantifying the proportion of delivered packets that meet the delay criterion should satisfy

$$\mathrm{FPP}\ (n, W, \delta) \geq 1\%$$

That is, the floor packet percentage must exceed 1%.

This means that for any window interval of 200 s at least 1% of transmitted timing packets will be received within a fixed cluster, starting at the observed floor delay, and having a range of 150 µs.

NOTE 1– The selection method (using sliding, overlapping or jumping windows) applicable to the network limit specified in this Recommendation is for further study.

NOTE 2 – The number of packets received within the fixed cluster range depends on the nominal packet rate. For example, with a nominal packet rate of one packet per second, FPP > 1% implies that two or more packets will be received within the fixed cluster range in each 200 s interval. The number of packets in a selection window is important for considering the tolerance limit of a slave clock.

For more details on the measurement methodology refer to clause I.5 of [ITU-T G.8260].

This network limit can be applied independently on the forward or the reverse direction of a packet timing flow. Consideration of the combined effect of both directions is for further study.

NOTE 3 – This network limit only applies for HRM-1. Many HRM-1 networks may exhibit much lower packet delay variation than indicated by this limit, and therefore this limit is considered very conservative. It does not describe the distribution of packet delays within the cluster range.

Other PDV metrics emulating the behaviour of a packet slave clock are currently under study and might be used in the future for specifying the PDV network limits in a less conservative way. Some information can be found in clause I.4 of [ITU-T G.8260].

The packet delay variation network limits for the HRM-2 are for further study. For HRM-2, different limits may apply, and may use different metrics.

Bibliography

[b-IEEE 802.1Qay] IEEE 802.1Qay™-2009, *IEEE Standard for Local and metropolitan area networks – Virtual Bridged Local Area Networks Amendment 10: Provider Backbone Bridge Traffic Engineering*.

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Printed in Switzerland
Geneva, 2012