International Telecommunication Union

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ITU-T **G.8275.1/Y.1369.1**

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Amendment 1
(08/2017)

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Precision time protocol telecom profile for phase/time synchronization with full timing support from the network

Amendment 1

Recommendation ITU-T G.8275.1/Y.1369.1 (2016) – Amendment 1

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Recommendation ITU-T G.8275.1/Y.1369.1

Precision time protocol telecom profile for phase/time synchronization with full timing support from the network

Amendment 1

Summary

Recommendation ITU-T G.8275.1/Y.1369.1 contains the ITU-T precision time protocol (PTP) profile for phase and time distribution with full timing support from the network. It provides the necessary details to utilize IEEE 1588 in a manner consistent with the architecture described in Recommendation ITU-T G.8275/Y.1369.

Amendment 1 provides the following updates:

–   added ITU-T G.8271 to references;

–   addition of a new definition: special port (3.2);

–   clarification on the use of logMessageInterval in Delay_Resp messages (6.2.8);

–   clarification on the behaviour of the T-BC Announce message contents when the T-BC has a parent clock;

–   incremented the minor revision number of the profileVersion (Annex A);

–   correction to the handling of the alternateMasterFlag;

–   added informative text on the handling of the synchronizationUncertain flag (Annex E);

–   added monitoring of a PTP MASTER port by a PTP PASSIVE port (Annex G);

–   updates to Announce message fields of currentUtcOffset and synchronizationUncertain when using PTP clock states (Appendix V);

–   update of Appendix VII;

–   added informative use cases for the use of the priority2 attribute (Appendix X);

–   added considerations on native access equipment (Appendix XI);

–   added monitoring alternate master time information provided by a peer PTP port (Appendix XII).

History

Edition	Recommendation	Approval	Study Group	Unique ID[*]
1.0	ITU-T G.8275.1/Y.1369.1	2014-07-22	15	11.1002/1000/12197
1.1	ITU-T G.8275.1/Y.1369.1 (2014) Cor. 1	2015-01-13	15	11.1002/1000/12397
2.0	ITU-T G.8275.1/Y.1369.1	2016-06-22	15	11.1002/1000/12815
2.1	ITU-T G.8275.1/Y.1369.1 (2016) Amd. 1	2017-08-29	15	11.1002/1000/13329

Keywords

Full timing support, IEEE 1588, phase and time synchronization, PTP, telecom profile.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not 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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Precision time protocol telecom profile for phase/time synchronization with full timing support from the network

Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.8275.1/Y.1369.1 (2016).

1   Scope

This Recommendation specifies a profile for telecommunication applications based on IEEE 1588 precision time protocol (PTP). The profile specifies the IEEE 1588 functions that are necessary to ensure network element interoperability for the delivery of accurate phase/time synchronization. The profile is based on the full timing support from the network architecture as described in [ITU-T G.8275] and definitions described in [ITU-T G.8260].

This version of the profile specifies the high-level design requirements, modes of operation for the exchange of PTP messages, the PTP protocol mapping, the best master clock algorithm (BMCA) options, as well as the PTP protocol configuration parameters.

NOTE – The parameters defined in the first version of the profile have been chosen based on the case where physical layer frequency support is provided.

This Recommendation also specifies some aspects necessary for use in a telecom environment that are outside the scope of, and complement the PTP profile.

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.781]   Recommendation ITU-T G.781 (2008), *Synchronization layer functions*.

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

[ITU-T G.8260]   Recommendation ITU-T G.8260 (2015), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8265.1]   Recommendation ITU-T G.8265.1/Y.1365.1 (2014), *Precision time protocol telecom profile for frequency synchronization*.

[ITU-T G.8271]   Recommendation ITU-T G.8271/Y.1366 (2016), *Time and phase synchronization aspects of packet networks.*

[ITU-T G.8271.1]   Recommendation ITU-T G.8271.1/Y.1366.1 (2013), *Network limits for time synchronization in packet networks*.

[ITU-T G.8272]   Recommendation ITU-T G.8272/Y.1367 (2012), *Timing characteristics of primary reference time clocks*.

[ITU-T G.8273]	Recommendation ITU-T G.8273/Y.1368 (2013), *Framework of phase and time clocks*.
[ITU-T G.8273.2]	Recommendation ITU-T G.8273.2/Y.1368.2 (2014), *Timing characteristics of telecom boundary clocks and telecom time slave clocks*.
[ITU-T G.8275]	Recommendation ITU-T G.8275/Y.1369 (2013), *Architecture and requirements for packet-based time and phase distribution*.
[IEEE 1588]	IEEE 1588-2008, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

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

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 special port: A PTP special port is a PTP port that translates between the native timing mechanism of a medium and PTP.

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AVAR	Allan Variance
BC	Boundary Clock
BMCA	Best Master Clock Algorithm
EEC	synchronous Ethernet Equipment Clock
ePRTC	Enhanced Primary Reference Time Clock
EUI	Extended Unique Identifier
FPM	Flicker Phase Modulation
GM	Grandmaster
GNSS	Global Navigation Satellite System
LAG	Link Aggregation
MVAR	Modified Allan Variance
OC	Ordinary Clock
PRC	Primary Reference Clock
PRS	Primary Reference Source
PRTC	Primary Reference Time Clock
PSD	Power Spectral Density
PTP	Precision Time Protocol

QL	Quality Level
SDH	Synchronous Digital Hierarchy
SSM	Synchronization Status Message
SSU	Synchronization Supply Unit
SSU-A	primary level SSU
SSU-B	secondary level SSU
ST2	Stratum 2
ST3E	Stratum 3 Enhanced
T-BC	Telecom Boundary Clock
TC	Transparent Clock
T-GM	Telecom Grandmaster
T-TC	Telecom Transparent Clock
T-TSC	Telecom Time Slave Clock
TLV	Type Length Value
TVAR	Time Variance
VLAN	Virtual Local Area Network
WPM	White Phase Modulation

5   Conventions

Within this Recommendation, the following conventions are used: the term PTP refers to the PTP version 2 protocol defined in [IEEE 1588]. PTP messages used within this Recommendation are defined in [IEEE 1588] and are identified using italicized text.

The term telecom boundary clock (T-BC) refers to a device consisting of a boundary clock (BC) as defined in [IEEE 1588] and this Recommendation, with additional performance characteristics defined in [ITU-T G.8273.2].

The term telecom transparent clock (T-TC) refers to a device consisting of a transparent clock (TC) as defined in [IEEE 1588], with additional performance characteristics for further study.

The term telecom grandmaster (T-GM) refers to a device consisting of a grandmaster (GM) clock as defined in [IEEE 1588] and this Recommendation, with additional performance characteristics for further study.

The term telecom time slave clock (T-TSC) refers to a device consisting of a slave-only ordinary clock (OC) as defined in [IEEE 1588] and this Recommendation, with additional performance characteristics defined in the Annex C of [ITU-T G.8273.2].

The term primary reference time clock (PRTC) refers to the clock defined in [ITU-T G.8272]. The term enhanced primary reference time clock (ePRTC) refers to an enhanced version of the PRTC, which is being studied.

6   Use of PTP for phase/time distribution

The 2002 version of the IEEE 1588 was developed by the IEEE initially to support the timing requirements of industrial automation, and defines the precision time protocol (PTP) designed to enable accurate time transfer in this context.

The 2008 version of IEEE 1588 (defined in [IEEE 1588]) contains features useful to the transport of the protocol over a wide area network, and introduces the concept of "profile", whereby aspects of the protocol may be selected and specified for a particular use other than the originally intended industrial automation.

A PTP profile has been defined in [ITU-T G.8265.1] to address applications requiring frequency synchronization only. This Recommendation defines another PTP profile, for telecom applications requiring accurate phase and time synchronization. It supports the specific architecture described in [ITU-T G.8275] in order to allow the distribution of phase/time with full timing support from the network, and is based on the 2008 version of PTP defined in [IEEE 1588].

In order to claim compliance with the telecom profile, the requirements of this Recommendation and the relevant requirements of [IEEE 1588], as referenced in Annex A, must be met.

The detailed aspects related to the telecom profile are described in the following clauses, while the profile itself is contained in Annex A. It follows the general rules for profile specification developed in [IEEE 1588].

This PTP telecom profile defines the parameters from [IEEE 1588] to be used in order to guarantee protocol interoperability between implementations and specifies the optional features, default values of configurable attributes and mechanisms that must be supported. However, it does not guarantee that the performance requirements of a given application will be met. These performance aspects are defined in other ITU-T Recommendations, and imply additional elements beyond the content of the PTP profile itself.

6.1 High-level design requirements

Clause 19.3.1.1 of [IEEE 1588] states:

"The purpose of a PTP profile is to allow organizations to specify specific selections of attribute values and optional features of PTP that, when using the same transport protocol, inter-work and achieve a performance that meets the requirements of a particular application."

For operation in a telecom network, some additional criteria are also required to be consistent with standard telecom synchronization practices. Therefore, the PTP profile for time and phase distribution must meet the following high-level requirements:

1) Mechanisms must be specified to allow interoperability between the various phase/time clocks belonging to the architecture defined in [ITU-T G.8275] and described in [ITU-T G.8273].

2) Mechanisms must permit consistent operation over managed wide area telecom networks.

3) Packet-based mechanisms must allow the synchronization network to be designed and configured in a fixed arrangement.

4) Protection schemes used by packet-based systems must be based on standard telecom operational practice and allow telecom time slave clocks the ability to take phase and time from multiple geographically separate telecom grandmaster clocks.

5) Phase/time reference source selection based on received phase/time traceability and local priority, as well as automatic establishment of the phase/time synchronization network topology, should be permitted.

6.2 PTP modes and options

6.2.1 PTP domains

A domain consists of a logical grouping of clocks communicating with each other using the PTP protocol.

PTP domains are used to partition a network within an administrative entity. The PTP messages and data sets are associated with a domain and therefore, the PTP protocol is independent for different domains.

In this PTP telecom profile, the default PTP domain number is 24, and the range of applicable PTP domain numbers is {24 – 43}.

NOTE − This range has been selected from the user-defined PTP domain number range defined in [IEEE 1588]. Although non-overlapping ranges have been considered for the different PTP telecom profiles so that interactions between the profiles are prevented, nothing precludes another industry from using the same user-defined PTP domain number range when defining a non-telecom PTP profile. It is the responsibility of the network operator to identify if the risk of unintentional interactions between PTP profiles exists, and to take the necessary actions to prevent such behaviour.

6.2.2 PTP messages used in the profile

This PTP profile uses the messages: *Sync*, *Follow_Up*, *Announce*, *Delay_Req*, and *Delay_Resp*.

The use of *Signalling* and *Management* messages is for further study.

Pdelay_Req, *Pdelay_Resp*, and *Pdelay_Resp_Follow_Up* messages are not used.

6.2.3 Types of PTP clocks supported in the profile

The ordinary clock (OC), boundary clock (BC) and transparent clock (TC) according to [IEEE 1588] are used in this profile.

There are two types of OCs:

1)   An OC that can only be a grandmaster (T-GM according to the architecture defined in [ITU-T G.8275], and as included in [ITU-T G.8272]).

2)   An OC that can only be a slave, i.e., slave-only OC (T-TSC according to the architecture defined in [ITU-T G.8275], and compliant with Annex C of [ITU-T G.8273.2]).

There are two types of BCs:

1)   A BC that can only be a grandmaster (T-GM according to the architecture defined in [ITU-T G.8275], and as included in [ITU-T G.8272]).

2)   A BC that can become a grandmaster and can also be slaved to another PTP clock (T-BC according to architecture defined in [ITU-T G.8275] and compliant with [ITU-T G.8273.2]).

NOTE − T-GM and grandmaster (GM) are different concepts; GM is a status defined in [IEEE 1588] that a PTP clock may obtain if it wins the best master clock algorithm (BMCA), while T-GM is a type of clock defined in the [ITU-T G.8275] architecture.

The transparent clock used in this profile (T-TC according to the architecture defined in [ITU-T G.8275] and the framework of phase and time clocks [ITU-T G.8273]) is the end-to-end transparent clock defined in [IEEE 1588]. It is not permitted to use peer-to-peer transparent clocks in this profile.

The mapping between these PTP clock types and the phase/time clocks defined in the [ITU-T G.8275] architecture is described in Table 1.

Table 1 – Mapping between [ITU-T G.8275] and PTP clock types

Clock type from [ITU-T G.8275]	Description	Clock type from [IEEE 1588]
T-GM	Master-only ordinary clock (master with a single PTP port, always a GM, cannot be slaved to another PTP clock)	OC

Table 1 – Mapping between [ITU-T G.8275] and PTP clock types

Clock type from [ITU-T G.8275]	Description	Clock type from [IEEE 1588]
	Master-only boundary clock (master with multiple PTP ports, always a GM, cannot be slaved to another PTP clock)	BC
T-BC	Boundary clock (may become a GM, or may be slaved to another PTP clock)	BC
T-TSC	Slave-only ordinary clock (always a slave, cannot become a GM)	OC
T-TC	Transparent clock	End-to-end TC

6.2.4 One-way versus two-way operation

PTP operation must be two-way in this profile in order to transport phase/time synchronization, because propagation delay must be measured. Therefore, only two-way mode is allowed in this profile.

6.2.5 One-step versus two-step clock mode

Both one-step and two-step clocks are supported in the profile. A clock compliant with the profile may use either a one-step clock or a two-step clock.

To be compliant with [IEEE 1588], a slave port must be capable of receiving and processing messages from both one-step clocks and two-step clocks, without any particular configuration.

6.2.6 Ethernet multicast addressing for PTP messages

This PTP telecom profile uses Ethernet multicast addressing for the transmission of all PTP messages.

For the PTP profile specified in this Recommendation, when using the PTP mapping defined in [IEEE 1588] Annex F, both the non-forwardable multicast address 01-80-C2-00-00-0E and forwardable multicast address 01-1B-19-00-00-00 are supported.

A T-GM, T-BC, T-TSC or T-TC clock compliant with this profile must be capable of handling both the non-forwardable multicast address 01-80-C2-00-00-0E and the forwardable multicast address 01-1B-19-00-00-00 on all its PTP-capable ports.

For a T-GM, T-BC and T-TSC clock, the choice of the multicast address is made by configuration on a per-port basis; all the PTP messages of a port must use the configured address for transmitting PTP messages to the remote PTP port. In case the remote PTP port is configured with the other address, the local PTP port must accept and process the received messages.

The default address depends on the operator policy. See information in Appendix III.

On transmission, the default mode for a T-TC does not require any configuration: the PTP messages retransmitted by the T-TC must use the same multicast destination address as the received PTP message. It is mandatory to support this default mode in transmission.

NOTE – This profile uses [IEEE 1588] Annex F, *Transport of PTP over IEEE802.3/Ethernet*, for the transport layer. In particular, according to the relevant Ethernet bridge models, the appropriate MAC address of the transmit Ethernet port is placed into the sourceAddress field of the header of the Ethernet frame encapsulating the PTP packets sent by any of the PTP clocks defined in this profile (i.e., T-GM, T-BC, T-TC or T-TSC).

This profile processes PTP messages with Ethernet multicast encapsulation. PTP messages with other encapsulations should be forwarded based on the forwarding rules of the respective transport protocol.

6.2.7 PTP mapping

This PTP telecom profile is based on the PTP mapping defined in [IEEE 1588] Annex F, *Transport of PTP over IEEE 802.3/Ethernet*.

Therefore, a PTP clock compliant with the profile described in this Recommendation must be compliant with [IEEE 1588] Annex F.

The transportSpecific field is used in this profile and must be set to "0".

In the scenarios currently considered, e.g., based on full timing support with T-BC and T-TC, the insertion of a virtual local area network (VLAN) tag in the frames carrying PTP messages is not allowed for T-GMs, T-BCs and T-TSC,. In this case, when receiving a PTP message within a frame containing a VLAN tag, this frame must be discarded by the T-GM, T-BC, and T-TSC.

Some specific T-TC based configurations are discussed in Appendix I.

Using VLAN tags in other scenarios is for further study.

6.2.8 Message rates

Within the scope of the profile, the following messages can be used and the corresponding indicated nominal rates must be respected:

– *Sync* messages (if used, *Follow_up* messages will have the same rate) – nominal rate: 16 packets-per-second.

– *Delay_Req*/*Delay_Resp* messages – nominal rate: 16 packets-per-second.

– *Announce* messages – nominal rate: 8 packets-per-second.

The requirements of section 7.7.2.1 of [IEEE 1588] must also be respected for the transmission of *Sync* and *Announce* messages. In addition, the time between successive *Sync* messages must not exceed twice the mean *Sync* interval specified above, and the time between successive *Announce* messages must not exceed twice the mean *Announce* interval specified above.

The transmission of *Delay_Req* messages is specified in section 9.5.11.2 of [IEEE 1588].

In addition to bullet 1 and bullet 2 of section 9.5.11.2 of [IEEE 1588], a clock compliant to this profile must follow one of the following options:

– Transmission time requirements according to bullet 3 of section 9.5.11.2 of [IEEE 1588], using an implementation-specific distribution. In this case, the PTP node must, with 90% confidence, issue *Delay_Req* messages with inter-message intervals within $\pm 30\%$ of $2^{\text{logMinDelayReqInterval}}$ seconds.

– Transmission time requirements specified in bullet 4 of clause 9.5.11.2 of [IEEE 1588].

In addition, the time between successive *Delay_Req* messages must not exceed $2^{\text{logMinDelayReqInterval}+1}$ seconds.

As per section 9.5.12 of [IEEE 1588], the Master sets the logMessageInterval in the header of Delay_Resp messages to a value accepted by the Master. In this profile that value is −4 (16 pps).

Additional background information concerning the *Delay_Req* message transmission specified in section 9.5.11.2 of [IEEE 1588] is included in Appendix II.

The use of *signalling* and *management* messages is for further study.

Within the scope of the profile, the following messages can be used and the corresponding indicated nominal rates must be respected:

– *Sync* messages (if used, *Follow_up* messages will have the same rate) – nominal rate: 16 packets-per-second.

– *Delay_Req/Delay_Resp* messages – nominal rate: 16 packets-per-second.

– *Announce* messages – nominal rate: 8 packets-per-second.

The requirements of clause 7.7.2.1 of [IEEE 1588] must also be respected for the transmission of *Sync* and *Announce* messages. In addition, the time between successive *Sync* messages must not exceed twice the mean *Sync* interval specified above, and the time between successive *Announce* messages must not exceed twice the mean *Announce* interval specified above.

The transmission of *Delay_Req* messages is specified in clause 9.5.11.2 of [IEEE 1588].

In addition to bullet 1 and bullet 2 of clause 9.5.11.2 of [IEEE 1588], a clock compliant to this profile must follow one of the following options:

– Transmission time requirements according to bullet 3 of clause 9.5.11.2 of [IEEE 1588], using an implementation specific distribution. In this case, the PTP node must, with 90% confidence, issue *Delay_Req* messages with inter-message intervals within ±30% of $2^{logMinDelayReqInterval}$ seconds.

– Transmission time requirements specified in bullet 4 of clause 9.5.11.2 of [IEEE 1588].

In addition, the time between successive *Delay_Req* messages must not exceed $2^{logMinDelayReqInterval+1}$ seconds.

Additional background information concerning the *Delay_Req* message transmission specified in clause 9.5.11.2 of [IEEE 1588] is included in Appendix II of this Recommendation.

The use of *Signaling* and *Management* messages is for further study.

6.3 Protection aspects and Alternate BMCA

6.3.1 Alternate BMCA

The PTP profile specified in this Recommendation uses an Alternate BMCA, as described in clause 9.3.1 of [IEEE 1588]. This Alternate BMCA differs from the default BMCA of [IEEE 1588] as follows:

a) The Alternate BMCA considers the per-port Boolean attribute masterOnly. If masterOnly is TRUE, the port is never placed in the SLAVE state, and will always go to the MASTER state. If masterOnly is FALSE, the port can be placed in the SLAVE state. The masterOnly attribute is set via the configurable port data set member portDS.masterOnly.

The default value and range of values for this attribute, for the ports of a BC or OC that can only be a GM (i.e., T-GM), are TRUE and {TRUE}.

The default value and range of values for this attribute, for the port of a slave-only OC (i.e., T-TSC) are FALSE and {FALSE}.

The default value and range of values for this attribute, for the ports of a BC that may or may not be a GM (i.e., T-BC) are TRUE and {TRUE, FALSE}.

Note that for a T-BC, the masterOnly attribute must be set to FALSE on at least one port in order for the T-BC to be able to synchronize to another clock.

b) The computation of E_{rbest} is according to the description provided in clause 9.3.2.3 of [IEEE 1588], with the exception that the E_{rbest} of a port r must be set to the empty set when the masterOnly attribute of this port r is set to TRUE, irrespective of any other consideration. This is so that the computation of E_{best} will not use the information contained

in any *Announce* messages received on a port r where the masterOnly attribute is set to TRUE.

c)   The Alternate BMCA allows for multiple clocks to be active GMs simultaneously (clocks with clockClass less than 128 cannot be a slave). If there are multiple active GMs, every clock that is not a GM is synchronized by a single GM in the PTP domain.

d)   The per-port attribute localPriority is assigned to each port r of a clock and is used in the determination of E_{rbest} and E_{best}. Each parent clock or foreign master clock data set, whose *Announce* information was received on the port r, is appended with the localPriority attribute of the local port r before the data set comparison defined in Figure 2 and Figure 3 below is invoked. The localPriority attribute is not transmitted in *Announce* messages. This attribute is used as a tie-breaker in the data set comparison algorithm, in the event that all other previous attributes of the data sets being compared are equal. The localPriority attribute is set via the configurable, unsigned integer, port data set member portDS.localPriority. The data type for this attribute is UInteger8. The range of values for this attribute is {1-255}. The default value for this attribute is 128. A clock compliant with this PTP profile is allowed to support a subset of the values defined in the range.

e)   The attribute localPriority is assigned to the local clock, to be used if needed when the data associated with the local clock, D_0, is compared with data on another potential GM received via an *Announce* message. The local clock localPriority attribute is set via the configurable, unsigned integer, default data set member defaultDS.localPriority. The data type for this attribute is UInteger8. The range of values for this attribute is {1-255}. The default value for this attribute is 128. A clock compliant with this PTP profile is allowed to support a subset of the values defined in the range.

f)   The data set comparison algorithm is modified according to Figures 2 and 3 in clause 6.3.7.

NOTE 1 − Because the value of the masterOnly attribute is, per definition, always TRUE on all PTP ports of a T-GM, the localPriority attribute is, in practice, not used for a T-GM.

NOTE 2 − For a T-GM, the Alternate BMCA output is in practice static and provides a recommended state = BMC_MASTER, because the masterOnly attribute = TRUE for all the PTP ports of a T-GM. The resulting decision code can be M1 or M2, depending on the status of the T-GM (i.e., clockClass value of the T-GM).

NOTE 3 − For a T-BC, the ports for which the masterOnly attribute is FALSE should be selected according to the network synchronization plan. One typical use case where this parameter should remain TRUE is to prevent timing from propagating from the access portion of the network to the core portion of the network.

NOTE 4 − The use of masterOnly is intended primarily to be used in two scenarios

1.   A PTP port of a T-GM;

2.   A PTP port of a T-BC that is facing the 'downstream' direction towards the access portion of a tree topology.

The use of the masterOnly parameter in other scenarios, such as on PTP ports participating in a ring architecture, may result in unintended operation, especially during re-configuration or topology changes.

6.3.2   Considerations on the use of the localPriority attributes

The localPriority attributes provide a powerful tool in defining the synchronization network architecture.

The use of the default values for these attributes as defined by the Alternate BMCA results in a timing-loop free synchronization network.

Proper planning will be mandatory to avoid timing-loops when configuring values different from the default ones.

6.3.3 Static clock attribute priority1

In this PTP profile, the clock attribute priority1 is static. It is initialized to a default value equal to the midpoint value, 128, of its range, and this value must not be changed.

The priority1 parameter is not used in this version of the PTP telecom profile. Future versions may consider using this attribute, this is for further study.

6.3.4 Clock attribute priority2

In this PTP profile, the clock attribute priority2 is configurable.

It is initialized to a default value, equal for T-GM and T-BC clocks to the midpoint value, 128, of its range {0-255}. The default value for T-TSC clocks is 255, and the range is {255}.

A T-GM or T-BC compliant with this PTP profile must support all the values of priority2 defined in the range. A T-TSC compliant with this profile must support, on reception, all the values of priority2 defined in the full IEEE 1588 range (i.e., {0-255}).

Appendix IV describes possible use cases for the priority2 attribute; Appendix X describes possible use cases for the priority2 attribute under Note 3 of Table 2; other cases are for further study. ~~In this PTP profile, the clock attribute priority2 is configurable.~~

~~It is initialized to a default value, equal for T-GM and T-BC clocks to the midpoint value, 128, of its range {0-255}. The default value for T-TSC clocks is 255, and the range is {255}.~~

~~A T-GM or T-BC compliant with this PTP profile must support all the values of priority2 defined in the range. A T-TSC compliant with this profile must support, on reception, all the values of priority2 defined in the full [IEEE1588] range (i.e., {0-255}).~~

~~Appendix IV describes possible use cases for the priority2 attribute; other cases are for further study.~~

6.3.5 Other clock attributes

A PTP clock compliant with this PTP profile must support all the values of clockClass, clockAccuracy, and offsetScaledLogVariance upon reception [shall not discard] defined in the full [IEEE1588] range.

The applicable values of the clock attribute clockClass are specified in 6.4.

NOTE – The behaviour on reception of a clockClass value not specified in Table 2 is for further study.

The following values of the clock attribute clockAccuracy apply for the following situations:

– 0x20 for a T-GM connected to an Enhanced Primary Reference Time Clock (ePRTC) in locked-mode (i.e., ePRTC traceable to global navigation satellite system (GNSS));

– 0x21 for a T-GM connected to a PRTC in locked-mode (i.e., PRTC traceable to GNSS);

– 0xFE for a T-GM not connected to an ePRTC in locked-mode nor to a PRTC in locked-mode;

– 0xFE for a T-BC, all the time.

The following values of the clock attribute offsetScaledLogVariance apply for the following situations:

– 0x4B32 for a T-GM connected to an ePRTC in locked-mode (i.e., ePRTC traceable to GNSS). This corresponds to TDEV of 10 ns, at observation interval of 10000 s. The corresponding value of PTP Variance (PTPVAR) is 1.271×10^{-16} s^2 (see Appendix IX);

– 0x4E5D for a T-GM connected to a PRTC in locked-mode (i.e., PRTC traceable to GNSS). This corresponds to TDEV of 30 ns, at observation interval of 10000 s. The corresponding value of PTP Variance (PTPVAR) is 1.144×10^{-15} s^2 (see Appendix IX);

–   0xFFFF for a T-GM not connected to an ePRTC in locked-mode nor to a PRTC in locked-mode;

–   0xFFFF for a T-BC, all the time.

6.3.6   State decision algorithm

The state decision algorithm applicable to the Alternate BMCA of the PTP profile specified in this Recommendation is given in Figure 1. After a decision is reached by use of this algorithm, the data sets of the local clock are updated as specified in clause 9.3.5 of [IEEE 1588]. Details on the use of the algorithm are given in clause 9.3.3 of [IEEE 1588].

6.3.7   Data set comparison algorithm

The data set comparison algorithm for the Alternate BMCA of the PTP profile specified in this Recommendation is given in Figures 2 and 3 below. With this algorithm, one clock is compared with another using the data sets representing those clocks, appended with the localPriority attribute. Details on the use of the algorithm are given in clause 9.3.4 of [IEEE 1588].

If either of the data sets, A or B, in Figures 2 and 3 contain the data of the parent clock or a foreign master clock, the corresponding localPriority for its data set is the localPriority of the local port r on which the information from that parent clock or foreign master clock has been received (see item (d) of clause 6.3.1).

If either of the data sets, A or B, in Figures 2 and 3 contain the data of the local clock, D_0, the corresponding localPriority for that data set is the localPriority of the local clock (see item (e) of clause 6.3.1).

NOTE 1 – It is recommended that the entire data set comparison algorithm described in Figures 2 and 3 be implemented even if some parameters are currently static, because they may be used in future versions of this Recommendation.

NOTE 2 – The block in Figure 2 "GM clockClass of A is 127 or less" enables different T-BCs in the network to be synchronized by different T-GMs when multiple T-GMs are deployed.
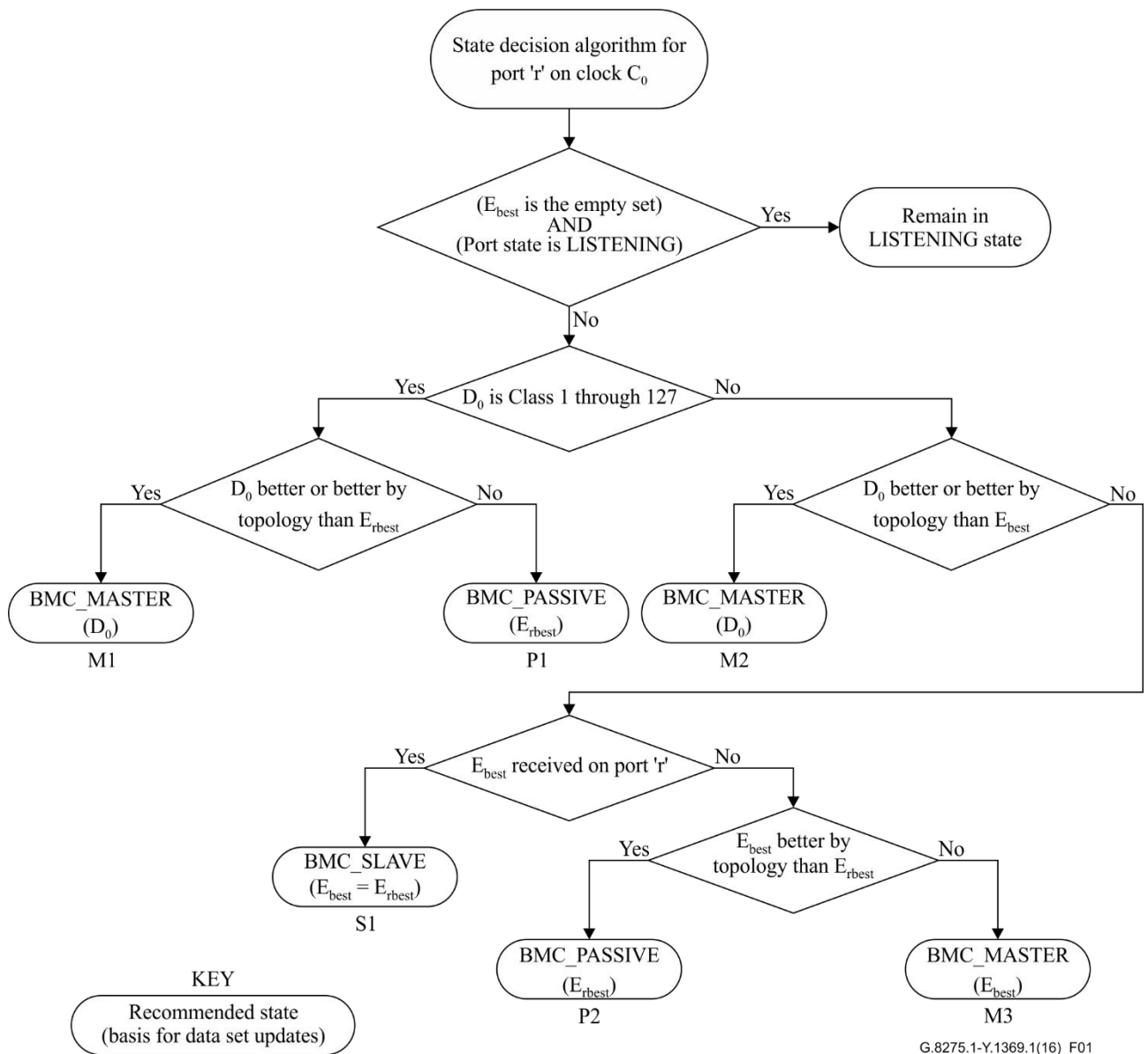
Figure 1 – State decision algorithm for Alternate BMCA
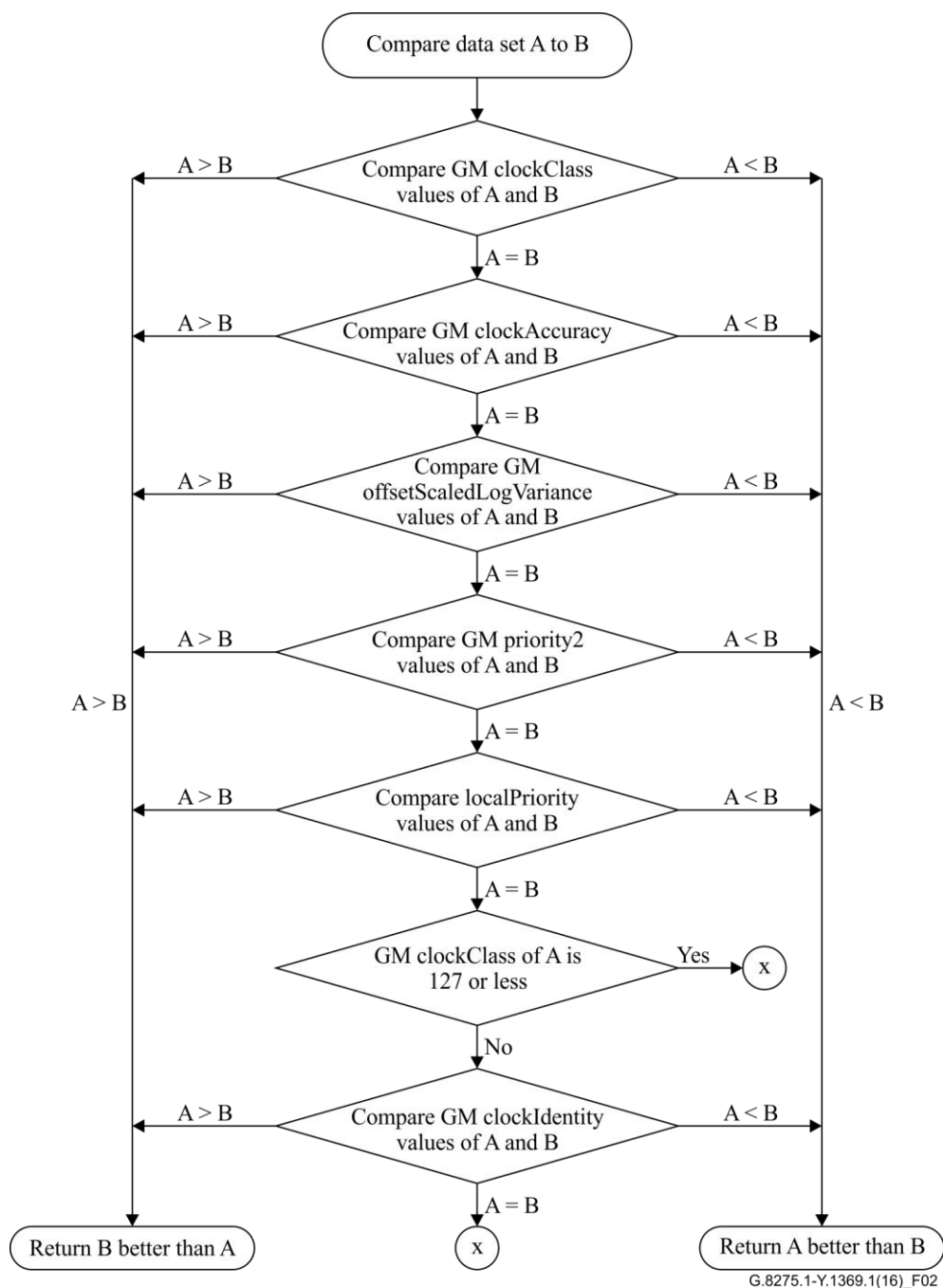
Figure 2 – Data set comparison algorithm, part 1, for Alternate BMCA
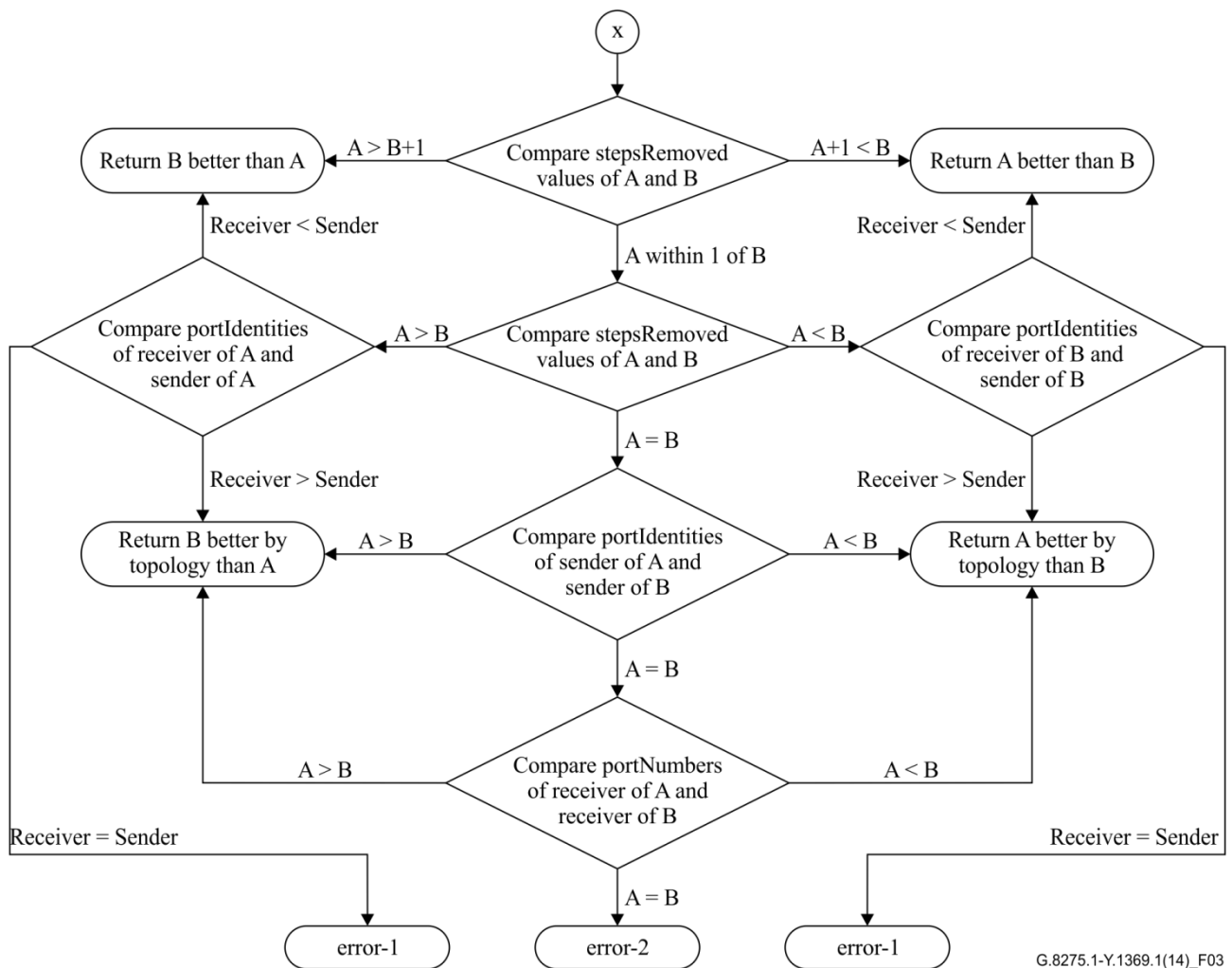
Figure 3 – Data set comparison algorithm, part 2, for Alternate BMCA

6.3.8 Unused PTP fields

Some PTP fields are not used in this PTP profile. This clause defines the actions applicable to these unused PTP fields.

Table A.8 in clause A.10 of this Recommendation defines the PTP common header flag values, and whether or not each flag is used in this profile.

In addition, the following fields are not used in this profile:

– The "controlField" in the common header of PTP messages is not used in this profile. This field must be ignored by the receiver for all types of PTP messages;

– The "priority1" field in the *Announce* message is not used, and must be set to a fixed value specified in clause 6.3.3.

When a PTP clock receives a PTP message with a field, whose use is not specified in this PTP profile, containing a value outside the allowed range, then this field of the PTP message must be ignored, without discarding the PTP message.

As an example, a PTP clock compliant with this PTP profile must ignore on reception the field value for the following fields. A clock compliant with this PTP profile must not update its local data sets with the ingress value for these fields:

– flagField – alternateMasterFlag;

– flagField – unicastFlag;

– flagField – PTP profile Specific 1;

–   flagField – PTP profile Specific 2.

When a PTP clock receives a PTP message with a field, whose use is specified in this PTP profile, containing a value outside the allowed range for reception, then this entire PTP message must be discarded. Except for the attributes clockClass, clockAccuracy, offsetScaledLogVariance, and priority2 (see clauses 6.3.4 and 6.3.5), the ranges for reception and for defaultDS members are the same.

As an example, a compliant clock must discard on reception the ingress packet (General and Event messages) when any of the following fields are outside of the allowed range for the profile:

–   domainNumber;

–   versionPTP.

The clock's local data set must not be updated with the ingress value.

NOTE 1 − If a clock receives an *Announce* message with the "priority1" field set to a value other than 128, and if the clock advertising this value is selected as the GM, then 128 must be re-advertised by the receiving clock. The unused attribute priority1 is ignored by the receiving clock for the purpose of the Alternate BMCA.

NOTE 2 – The allowed ranges for reception for the clock attributes priority2, clockClass, clockAccuracy, and offsetScaledLogVariance are the respective full [IEEE1588] ranges, see clauses 6.3.4 and 6.3.5.

6.4   Phase/time traceability information

To deliver phase/time traceability information, the clockClass values described in Table 2 below must be used in this PTP telecom profile. Additional information for interworking purposes is provided in Table 4.

The frequencyTraceable flag present in the header of the PTP messages is defined in this profile as follows: if the PTP clock is traceable to a PRTC in locked mode or to a primary reference clock (PRC), e.g., using a PRC-traceable physical layer frequency input, then this parameter must be set to TRUE, otherwise it must be FALSE. This flag is not used in the Alternate BMCA defined in clause 6.3; the values provided for this flag in Table 2 can be used by a network operator for monitoring purposes or by end applications to take definitive action as described in Appendix VIII.

When a T-GM first enters holdover, it downgrades the clockClass value that it uses to 7. It then calculates if the time error at its output is still within the holdover specification. When the T-GM determines that the time error at its output has exceeded the holdover specification, it downgrades the clockClass value that it uses to 140, 150 or 160 depending on the quality of its frequency reference (internal oscillator or received physical layer frequency signal on an external interface).

When a T-BC first enters holdover, it downgrades the clockClass value that it uses to 135. It then calculates if the time error at its output is still within the holdover specification. When the T-BC determines that the time error at its output has exceeded the holdover specification, it downgrades the clockClass value that it uses to 165 (internal oscillator or received physical layer frequency signal on an external interface).

NOTE 1 – The applicable holdover specification depends on the design and budgeting of the synchronization network. See Appendix V of [ITU-T G.8271.1] for examples of network budgeting. A typical value for the holdover budget, described in the failure scenario (b) depicted in [ITU-T G.8271.1] Table V.1, when using the T-GM or T-BC for holdover while still meeting a total time error of 1.5 µs, is 400 ns.

NOTE 2 – When the term clockClass is used with respect to the property of the individual PTP clock (T-GM, T-BC, T-TSC) it is referring to data set member defaultDS.clockQuality.clockClass.

NOTE 3 – For the T-BC, the traceability information of the currently selected best master clock will be passed to the downstream nodes, as per PTP. This means that the attributes and flags in the PTP header will always reflect the phase/time traceability information from the current parent clock, regardless of the frequency traceability of the T-BC's physical layer clock. Failure scenarios including holdover are for further study.

Table 2 – Applicable clockClass values

Phase/time traceability description	defaultDS. clockQuality. clockClass	frequencyTraceable flag	timeTraceable flag
T-GM connected to a PRTC in locked mode (e.g., PRTC traceable to GNSS)	6	TRUE	TRUE
T-GM in holdover, within holdover specification, traceable to Category 1 frequency source (Note 1)	7	TRUE	TRUE
T-GM in holdover, within holdover specification, non-traceable to Category 1 frequency source (Note 1)	7	FALSE	TRUE
T-BC in holdover, within holdover specification, traceable to Category 1 frequency source (Note 1)	135	TRUE	TRUE
T-BC in holdover, within holdover specification, non-traceable to Category 1 frequency source (Note 1)	135	FALSE	TRUE
T-GM in holdover, out of holdover specification, traceable to Category 1 frequency source (Note 1)	140	TRUE	FALSE
T-GM in holdover, out of holdover specification, traceable to Category 2 frequency source (Note 1)	150	FALSE	FALSE
T-GM in holdover, out of holdover specification, traceable to Category 3 frequency source (Note 1)	160	FALSE	FALSE
T-BC in holdover, out of holdover specification (Note 1)	165	(Note 2)	FALSE
T-GM or T-BC without time reference since start-up	248	(Note 2)	FALSE
Slave only OC (does not send *Announce* messages)	255	(Note 2)	As per PTP

NOTE 1 – The holdover specification threshold controlling the time spent advertising clockClass values 7 or 135 could be set to zero so that the T-GM or T-BC would advertise a degraded clockClass value directly after losing traceability to a PRTC. In this case, initially after advertising clockClass values 140, 150, 160, or 165, a clock may still be within the holdover specification.

NOTE 2 – The frequencyTraceable flag may be TRUE or FALSE, depending on the availability of a PRC-traceable physical layer frequency input signal.

NOTE 3 – As an option, the clockClass range of a T-BC can be extended from (135, 165, 248) to (135, 140, 150, 160, 165, 248) for some cases, where (a) 140, 150, 160, and 165 are related to the quality of the frequency reference, (b) the applicable circumstances of 140, 150, and 160 are the same as for the T-GM, and (c) 165 corresponds to synchronous Ethernet equipment clock (EEC). Details are in Appendix X. If this option is used, then in a single PTP domain, all PTP clocks should implement this option (and should not be intermixed with clocks that do not implement this option). Details are for further study.

NOTE 4 – The term "holdover" in this table refers to "time holdover".

NOTE 5 – Refer to Appendix VII for more information about the behaviour of a T-BC that was previously synchronizing to a T-GM or a T-BC that is advertising 'within holdover specification' or 'out of holdover specification'.

Table 3 describes how the clock quality levels (QLs) defined in [ITU-T G.781] are mapped to Category 1, 2 and 3 frequency sources used in Table 2.

Table 3 – Mapping of [ITU-T G.781] clock QLs to Category 1, 2, 3 frequency sources

Category (in Table 2 and 4)	ITU-T G.781 option I QLs	ITU-T G.781 option II QLs
Category 1 frequency source	QL-PRC	QL-PRS
Category 2 frequency source	QL-SSU-A	QL-ST2
Category 3 frequency source	QL-SSU-B	QL-ST3E
NOTE – Other frequency source categories, while not used in Table 2, are possible. An example is a category containing QL-EEC1 and QL-EEC2.		

NOTE 4 – The case of a T-BC acting as a GM, with an external phase/time input coming from a PRTC, is handled by means of a virtual PTP port with associated E_{rbest} attributes as described in Annex C of this Recommendation. The general case of a T-BC with a phase/time external synchronization input different from PRTC is for further study.

Table 4 presents a subset of the clockClass values of Table 2 based on the quality of the frequency reference, and the mapping of the corresponding values used by some equipment deployed prior to this Recommendation.

NOTE 5 – When interoperability with equipment deployed prior to this Recommendation is needed, both sets of clockClass values would need to be supported. Other aspects may be required for full interoperability.

Table 4 – clockClass values for equipment deployed prior to this Recommendation

Phase/time traceability description	Values defined in Table 2	Values prior to this Rec.
T-GM connected to a PRTC in locked mode (e.g., PRTC traceable to GNSS)	6	6
T-GM in holdover, out of holdover specification, traceable to Category 1 frequency source (Note 1)	140	7
T-GM in holdover, out of holdover specification, traceable to Category 2 frequency source (Note 1)	150	(Note 2)
T-GM in holdover, out of holdover specification, traceable to Category 3 frequency source (Note 1)	160	52
T-BC in holdover, out of holdover specification, using unspecified frequency source (Note 1)	165	187
Slave only OC (does not send *Announce* messages)	255	255
NOTE 1 – Initially after advertising clockClass values greater than 6, a clock may still be within the holdover specification. NOTE 2 – Refer to the applicable value specified for the equipment. NOTE 3 – The term "holdover" in this table refers to "time holdover".		

In order to deliver phase/time traceability information, the clockClass values described in Table 2 below must be used in this PTP telecom profile. Additional information for interworking purposes is provided in Table 4.

The frequencyTraceable flag present in the header of the PTP messages is defined in this profile as follows: if the PTP clock is traceable to a PRTC in locked mode or to a primary reference clock (PRC), e.g., using a PRC-traceable physical layer frequency input, then this parameter must be set to TRUE, otherwise it must be FALSE. This flag is not used in the Alternate BMCA defined in clause 6.3; the values provided for this flag in Table 2 can be used by a network operator for monitoring purposes or by end applications to take definitive action as described in Appendix VIII.

When a T-GM first enters holdover, it downgrades the clockClass value that it uses to 7. It then calculates if the time error at its output is still within the holdover specification. When the T-GM determines that the time error at its output has exceeded the holdover specification, it downgrades the clockClass value that it uses to 140, 150 or 160 depending on the quality of its frequency reference (internal oscillator or received physical layer frequency signal on an external interface).

When a T-BC first enters holdover, it downgrades the clockClass value that it uses to 135. It then calculates if the time error at its output is still within the holdover specification. When the T-BC determines that the time error at its output has exceeded the holdover specification, it downgrades the clockClass value that it uses to 165 (internal oscillator or received physical layer frequency signal on an external interface).

NOTE 1 – The applicable holdover specification depends on the design and budgeting of the synchronization network. See Appendix V of [ITU-T G.8271.1] for examples of network budgeting. A typical value for the holdover budget, described in the failure scenario (b) depicted in [ITU-T G.8271.1] Table V.1, when using the T-GM or T-BC for holdover while still meeting a total time error of 1.5 µs, is 400 ns.

Table 2 – Applicable clockClass values

Phase/time traceability description	defaultDS. clockQuality. clockClass	frequencyTraceable flag	timeTraceable flag
T-GM connected to a PRTC in locked mode (e.g., PRTC traceable to GNSS)	6	TRUE	TRUE
T-GM in holdover, within holdover specification, traceable to Category 1 frequency source (Note 1)	7	TRUE	TRUE
T-GM in holdover, within holdover specification, non-traceable to Category 1 frequency source (Note 1)	7	FALSE	TRUE
T-BC in holdover, within holdover specification, traceable to Category 1 frequency source (Note 1)	135	TRUE	TRUE
T-BC in holdover, within holdover specification, non-traceable to Category 1 frequency source (Note 1)	135	FALSE	TRUE
T-GM in holdover, out of holdover specification, traceable to Category 1 frequency source (Note 1)	140	TRUE	FALSE
T-GM in holdover, out of holdover specification, traceable to Category 2 frequency source (Note 1)	150	FALSE	FALSE
T-GM in holdover, out of holdover specification, traceable to Category 3 frequency source (Note 1)	160	FALSE	FALSE
T-BC in holdover, out of holdover	165	(Note 2)	FALSE

Table 2 – Applicable clockClass values

Phase/time traceability description	defaultDS. clockQuality. clockClass	frequencyTraceable flag	timeTraceable flag
specification (Note 1)			
T-GM or T-BC without time reference since start-up	248	(Note 2)	FALSE
Slave only OC (does not send *Announce* messages)	255	(Note 2)	As per PTP
NOTE 1 – The holdover specification threshold controlling the time spent advertising clockClass values 7 or 135 could be set to zero so that the T-GM or T-BC would advertise a degraded clockClass value directly after losing traceability to a PRTC. In this case, initially after advertising clockClass values 140, 150, 160, or 165, a clock may still be within the holdover specification. NOTE 2 – The frequencyTraceable flag may be TRUE or FALSE, depending on the availability of a PRC-traceable physical layer frequency input signal. NOTE 3 – As an option, the clockClass range of a T-BC can be extended from (135, 165, 248) to (135, 140, 150, 160, 165, 248) for some cases, where (a) 140, 150, 160, and165 are related to the quality of the frequency reference, (b) the applicable circumstances of 140, 150, and 160 are the same as for the T-GM, and (c) 165 corresponds to synchronous Ethernet equipment clock (EEC). If this option is used, then in a single PTP domain, all PTP clocks should implement this option (and should not be intermixed with clocks that do not implement this option). Details are for further study. NOTE 4 – The term "holdover" in this table refers to "time holdover".				

Table 3 describes how the clock quality levels (QLs) defined in [ITU-T G.781] are mapped to Category 1, 2 and 3 frequency sources used in Table 2.

Table 3 – Mapping of [ITU-T G.781] clock QLs to Category 1, 2, 3 frequency sources

Category (in Table 2)	ITU-T G.781 option I QLs	ITU-T G.781 option II QLs
Category 1 frequency source	QL-PRC	QL-PRS
Category 2 frequency source	QL-SSU-A	QL-ST2
Category 3 frequency source	QL-SSU-B	QL-ST3E

NOTE 2 – The case of a T-BC acting as a GM, with an external phase/time input coming from a PRTC, is handled by means of a virtual PTP port with associated E_{rbest} attributes as described in Annex C of this Recommendation. The general case of a T-BC with a phase/time external synchronization input different from PRTC is for further study.

Table 4 presents a subset of the clockClass values of Table 2 based on the quality of the frequency reference, and the mapping of the corresponding values used by some equipment deployed prior to this Recommendation.

NOTE 3 – When interoperability with equipment deployed prior to this Recommendation is needed, both sets of clockClass values would need to be supported. Other aspects may be required for full interoperability.

**Table 4 – clockClass values for equipment deployed
prior to this Recommendation**

Phase/time traceability description	Values defined in Table 2	Values prior to this Rec.
T-GM connected to a PRTC in locked mode (e.g., PRTC traceable to GNSS)	6	6
T-GM in holdover, out of holdover specification, traceable to Category 1 frequency source (Note 1)	140	7
T-GM in holdover, out of holdover specification, traceable to Category 2 frequency source (Note 1)	150	(Note 2)
T-GM in holdover, out of holdover specification, traceable to Category 3 frequency source (Note 1)	160	52
T-BC in holdover, out of holdover specification, using unspecified frequency source (Note 1)	165	187
Slave only OC (does not send *Announce* messages)	255	255
NOTE 1 – Initially after advertising clockClass values greater than 6, a clock may still be within the holdover specification. NOTE 2 – Refer to the applicable value specified for the equipment.		

7   ITU-T PTP profile for phase/time distribution with full timing support from the network

The PTP profile for phase/time distribution with full timing support from the network is contained in Annex A.

8   Security aspects

For further study.

Annex A

ITU-T PTP profile for phase/time distribution with full timing support from the network

(This annex forms an integral part of this Recommendation.)

This annex contains the PTP telecom profile for phase/time distribution with full timing support from the network, as required by [IEEE 1588]. In order to claim compliance with this PTP telecom profile, the requirements in this annex and in the body of this Recommendation must both be met.

A.1   Profile identification

profileName: ITU-T PTP profile for phase/time distribution with full timing support from the network

profileVersion: 2.1

profileIdentifier: 00-19-A7-01-02-01

This profile is specified by ITU-T.

A copy may be obtained from www.itu.int.

NOTE 1 – Version 1 of this profile enforced a limited range on acceptable values for clockClass, clockAccuracy, offsetScaledLogVariance and, for the T-TSC, priority2. Reception of values outside of the acceptable range caused the Announce message to be discarded. Version 2 of the profile increases the range of acceptable values to the full range of PTP. In networks deploying ePRTCs, which use new values of clockAccuracy and offsetScaledLogVariance that are outside of the version 1 range, all clocks need to use version 2 of the profile. If no ePRTCs are to be deployed in the network, then the network can operate with a mixture of version 1 and version 2 clocks.

NOTE 2 – Version 2.1 is backwards compatible with version 2.0. Equipment with version 2.1 may be deployed in the same network as equipment with version 2.0. Version 2.1 adds additional optional functionality that is not present in version 2.0.

profileName: ITU-T PTP profile for phase/time distribution with full timing support from the network

profileVersion: 2.0

profileIdentifier: 00-19-A7-01-02-00

This profile is specified by ITU-T.

A copy may be obtained from www.itu.int.

NOTE – Version 1 of this profile enforced a limited range on acceptable values for clockClass, clockAccuracy, offsetScaledLogVariance and, for the T-TSC, priority2. Reception of values outside of the acceptable range caused the Announce message to be discarded. Version 2 of the profile increases the range of acceptable values to the full range of PTP. In networks deploying ePRTCs, which use new values of clockAccuracy and offsetScaledLogVariance that are outside of the version 1 range, all clocks need to use version 2 of the profile. If no ePRTCs are to be deployed in the network, then the network can operate with a mixture of version 1 and version 2 clocks.

A.2   PTP attribute values

The default values and ranges of the PTP attributes for use in this profile are contained in Tables A.1, A.2, A.3, A.4, A.5, A.6 and A.7. For the attributes clockClass, clockAccuracy, offsetScaledLogVariance, and priority2, the ranges shown are those for the defaultDS.

NOTE – A boundary clock follows the rules of [IEEE 1588] for selection of parent clock, updating of parentDS, and transmission of Announce messages, so it may transmit values different from the defaultDS values.

Attributes not specified by this profile must use the default initialization values and ranges defined in [IEEE 1588].

These tables provide a default initialization value and range for each data set member for:

– Telecom grandmaster: ordinary clock or boundary clock that can only act as a GM (T-GM according to [ITU-T G.8275] – first PTP clock of the chain);

– Telecom time slave clock: ordinary clock with a clockClass = 255 (T-TSC according to [ITU-T G.8275] – last PTP clock of the chain);

– Telecom boundary clock: boundary clock that may or may not be a GM; such a clock will be a GM if it is the best clock in the network (T-BC according to [ITU-T G.8275] – intermediate PTP clocks of the chain);

– Telecom transparent clock: end-to-end transparent clock (T-TC according to [ITU-T G.8275] – intermediate PTP clock of the chain).

The mapping between these PTP clock types and the phase/time clocks defined in the [ITU-T G.8275] architecture is described in Table 1, clause 6.2.3.

The attributes defined in Tables A.6 and A.7 for a transparent clock are optional.

Table A.1 − defaultDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Telecom time slave clock requirements		Telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.1.2.1	defaultDS.twoStepFlag (static)	As per PTP	{FALSE, TRUE}	As per PTP	{FALSE, TRUE}	As per PTP	{FALSE, TRUE}
8.2.1.2.2	defaultDS.clockIdentity (static)	As per PTP, based on EUI-64 format	As per PTP	As per PTP, based on EUI-64 format	As per PTP	As per PTP, based on EUI-64 format	As per PTP
8.2.1.2.3	defaultDS.numberPorts (static)	1 for OC As per PTP for BC	{1} for OC As per PTP for BC	1	{1}	As per PTP	As per PTP
8.2.1.3.1.1	defaultDS.clockQuality. clockClass (dynamic)	248	{6, 7, 140, 150, 160, 248}	255	{255}	248	{135, 165, 248}
8.2.1.3.1.2	defaultDS.clockQuality. clockAccuracy (dynamic)	0xFE	{0x20, 0x21, 0xFE} (Note)	0xFE	{0xFE}	0xFE	{0xFE}
8.2.1.3.1.3	defaultDS.clockQuality. offsetScaledLogVariance (dynamic)	0xFFFF	{0x4B32, 0x4E5D, 0xFFFF} (Note)	0xFFFF	{0xFFFF}	0xFFFF	{0xFFFF}

Table A.1 – defaultDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Telecom time slave clock requirements		Telecom boundary clock requirements	
8.2.1.4.1	defaultDS.priority1 (configurable)	128	{128}	128	{128}	128	{128}
8.2.1.4.2	defaultDS.priority2 (configurable)	128	{0-255}	255	{255}	128	{0-255}
8.2.1.4.3	defaultDS.domainNumber (configurable)	24	{24-43}	24	{24-43}	24	{24-43}
8.2.1.4.4	defaultDS.slaveOnly (configurable)	FALSE	{FALSE}	TRUE	{TRUE}	FALSE	{FALSE}
New member	defaultDS.localPriority (configurable)	128	{1-255}	128	{1-255}	128	{1-255}
New member	defaultDS.maxStepsRemoved (configurable)	255	{1-255}	255	{1-255}	255	{1-255}
NOTE – Examples of applicable values are shown in clause 6.3.5.							

Table A.2 – currentDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Telecom time slave clock requirements		Telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.2.2	currentDS.stepsRemoved (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.2.3	currentDS.offsetFromMaster (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.2.4	currentDS.meanPathDelay (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP

Table A.3 – parentDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Telecom time slave clock requirements		Telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.3.2	parentDS.parentPort Identity (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.3.3	parentDS.parentStats (dynamic)	(Note)	(Note)	(Note)	(Note)	(Note)	(Note)
8.2.3.4	parentDS.observedP arentOffsetScaledL ogVariance (dynamic)	(Note)	(Note)	(Note)	(Note)	(Note)	(Note)
8.2.3.5	parentDS.observedP arentClockPhaseCh angeRate (dynamic)	(Note)	(Note)	(Note)	(Note)	(Note)	(Note)
8.2.3.6	parentDS.grandmast erIdentity (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.3.7	parentDS.grandmast erClockQuality (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.3.8	parentDS.grandmast erPriority1 (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.3.9	parentDS.grandmast erPriority2 (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
NOTE – As per PTP, not applicable for this profile.							

Table A.4 – timePropertiesDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Telecom time slave clock requirements		Telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.4.2	timePropertiesDS.curr entUtcOffset (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.4.3	timePropertiesDS.curr entUtcOffsetValid (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}

Table A.4 – timePropertiesDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Telecom time slave clock requirements		Telecom boundary clock requirements	
8.2.4.4	timePropertiesDS.leap 59 (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.5	timePropertiesDS.leap 61 (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.6	timePropertiesDS.tim eTraceable (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.7	timePropertiesDS.freq uencyTraceable (dynamic)	FALSE	{FALSE, TRUE} Note	FALSE	{FALSE, TRUE} Note	FALSE	{FALSE, TRUE} Note
8.2.4.8	timePropertiesDS.ptp Timescale (dynamic)	TRUE	{TRUE}	TRUE	{TRUE}	TRUE	{TRUE}
8.2.4.9	timePropertiesDS.tim eSource (dynamic)	0xA0	As per PTP	0xA0	As per PTP	0xA0	As per PTP

NOTE – If the clock is traceable to a PRTC in locked mode or a PRC (e.g., using a PRC-traceable physical layer frequency input), then this parameter must be set to TRUE, otherwise it must be FALSE.

Table A.5 – portDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Master port requirements of telecom grandmaster		Slave port requirements of telecom time slave clock		Telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.5.2.1	portDS.portIdentity.clockI dentity (static)	As per PTP, based on EUI-64 format	As per PTP	As per PTP, based on EUI-64 format	As per PTP	As per PTP, based on EUI-64 format	As per PTP
8.2.5.2.1	portDS.portIdentity.portN umber (static)	1 for OC As per PTP for BC	{1} for OC As per PTP for BC	1	{1}	As per PTP	As per PTP
8.2.5.3.1	portDS.portState (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.5.3.2	portDS.logMinDelayReqI nterval (dynamic)	−4	{−4}	−4	{−4}	−4	{−4}

Table A.5 – portDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Master port requirements of telecom grandmaster		Slave port requirements of telecom time slave clock		Telecom boundary clock requirements	
8.2.5.3.3	portDS.peerMeanPathDelay (dynamic)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)
8.2.5.4.1	portDS.logAnnounceInterval (configurable)	−3	{−3}	−3 (Note 2)	{−3} (Note 2)	−3	{−3}
8.2.5.4.2	portDS.announceReceiptTimeout (configurable)	3	{3 – z} z is FFS	3	{3 – z} z is FFS	3	{3 – z} z is FFS
8.2.5.4.3	portDS.logSyncInterval (configurable)	−4	{−4}	−4 (Note 2)	{−4} (Note 2)	−4	{−4}
8.2.5.4.4	portDS.delayMechanism (configurable)	01	{01}	01	{01}	01	{01}
8.2.5.4.5	portDS.logMinPdelayReqInterval (configurable)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)
8.2.5.4.6	portDS.versionNumber (configurable)	2	{2}	2	{2}	2	{2}
New member	portDS. masterOnly (configurable)	TRUE	{TRUE}	FALSE	{FALSE}	TRUE	{TRUE, FALSE}
New member	portDS.localPriority (configurable)	128	{1-255}	128	{1-255}	128	{1-255}
NOTE 1 – As per PTP, not applicable for this profile.							
NOTE 2 – This type of message is not sent by a slave-only OC.							

Table A.6 − transparentClockDefaultDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom transparent clock requirements	
		Default initialization value	Range
8.3.2.2.1	transparentClockDefaultDS.clockIdentity (static)	As per PTP, based on EUI-64 format	As per PTP
8.3.2.2.2	transparentClockDefaultDS.numberPorts (static)	As per PTP for TC	As per PTP for TC
8.3.2.3.1	transparentClockDefaultDS.delayMechanism (configurable)	01	{01}
8.3.2.3.2	transparentClockDefaultDS.primaryDomain (configurable)	24	{24-43}

Table A.7 – transparentClockPortDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom transparent clock requirements	
		Default initialization value	Range
8.3.3.2.1	transparentClockPortDS.portIdentity (static)	As per PTP, based on EUI-64 format	As per PTP
8.3.3.3.1	transparentClockPortDS.logMinPdelayReqInterval (dynamic)	(Note 1)	(Note 1)
8.3.3.3.2	transparentClockPortDS.faultyFlag (dynamic)	FALSE	{FALSE, TRUE}
8.3.3.3.3	transparentClockPortDS.peerMeanPathDelay (dynamic)	(Note 1)	(Note 1)
NOTE 1 − As per PTP, not applicable for this profile			

A.3 PTP options

A.3.1 Node types required, permitted, or prohibited

In this profile, the permitted node types are: ordinary clocks, boundary clocks and end-to-end transparent clocks.

In this profile, the prohibited node types are: peer-to-peer transparent clocks.

A.3.2 One-step versus two-step clock mode

Both one-step and two-step clocks are permitted. A clock must be capable of receiving and handling messages transmitted from both one-step and two-step clocks. A clock is not required to support both one-step and two-step mode for transmitting messages.

A.3.3 Transport mechanisms required, permitted, or prohibited

In this profile, the required transport mechanism is IEEE 802.3/Ethernet, as per Annex F of [IEEE 1588]. Both the non-forwardable multicast address, 01-80-C2-00-00-0E, and the forwardable multicast address, 01-1B-19-00-00-00, are required to be supported for compliance with this profile.

All other transport mechanisms are for further study within the scope of this profile.

A.3.4 Unicast messages

All messages are sent multicast, using one of the two multicast addresses in clause A.3.3. The unicast mode is not permitted in this version of the profile.

A.4 Best master clock algorithm options

This profile uses the Alternate BMCA described in clause 6.3 of this Recommendation.

A.5 Path delay measurement option (delay request/delay response)

The delay request/delay response mechanism is used in this profile. The peer delay mechanism must not be used in this profile.

A.6 Clock identity format

The use of IEEE EUI-64 to generate the clock identity must be supported as indicated in clause 7.5.2.2.2 of [IEEE 1588]. Non-IEEE clockIdentity formats are not supported.

A.7 Configuration management options

Management aspects are for further study, and will be specified in a future version of this profile.

A.8 Security aspects

Security aspects are for further study. The experimental security protocol of Annex K of [IEEE 1588] is not used.

A.9 Other optional features of IEEE 1588

Other optional features of [IEEE 1588] are not used in this version of the profile. These include unicast message negotiation (clause 16.1 of [IEEE 1588]), alternate timescales (clause 16.3 of [IEEE 1588]), grandmaster clusters (clause 17.3 of [IEEE 1588]), alternate master (clause 17.4 of [IEEE 1588]), unicast discovery (clause 17.5 of [IEEE 1588]), acceptable master table (clause 17.6 of [IEEE 1588]), and the experimental cumulative frequency scale factor offset (Annex L of [IEEE 1588]).

A.10 PTP common header flags

The PTP common header flag values, and whether or not each flag is used in this profile, are given in Table A.8.

NOTE − Some of these flags are used only in certain PTP messages, and not in all the PTP messages, see [IEEE 1588] clause 13.3.2.6. The following rule defined in [IEEE 1588] clause 13.3.2.6, must be respected: "For message types where the bit is not defined in Table 20 of [IEEE 1588], the values shall be FALSE."

Table A.8 − PTP flags

Flag	Value to be sent	Behaviour for the receiving node
alternateMasterFlag	FALSE	Flag is ignored
twoStepFlag	As per PTP	Used
unicastFlag	FALSE	Flag is ignored
PTP profile Specific 1	FALSE	Flag is ignored
PTP profile Specific 2	FALSE	Flag is ignored
Reserved	FALSE	Reserved by PTP and flag is ignored
leap61	As per PTP	Used
leap59	As per PTP	Used
currentUtcOffsetValid	As per PTP	Used
ptpTimescale	TRUE	Used
timeTraceable	See Table 2	Used
frequencyTraceable	See Table 2	Used
Octet 1, Bit 6	(Note 1)	(Note 1)
NOTE 1 – An additional flag "synchronizationUncertain" has been defined in Annex E; the use of the "synchronizationUncertain" flag is optional.		

Table A.8 – PTP flags

Octet	Bit	Flag	Value to be sent	Behaviour for the receiving node
0	0	alternateMasterFlag	FALSE	As per PTP
0	1	twoStepFlag	As per PTP	Used
0	2	unicastFlag	FALSE	Flag is ignored
0	5	PTP profile Specific 1	FALSE	Flag is ignored
0	6	PTP profile Specific 2	FALSE	Flag is ignored
0	7	Reserved	FALSE	Reserved by PTP and flag is ignored
1	0	leap61	As per PTP (Note 2)	Used
1	1	leap59	As per PTP (Note 2)	Used
1	2	currentUtcOffsetValid	As per PTP (Note 3)	Used (Notes 3, 4)
1	3	ptpTimescale	TRUE	Used
1	4	timeTraceable	See Table 2	Used
1	5	frequencyTraceable	See Table 2	Used
1	6	(Note 1)	(Note 1)	(Note 1)

NOTE 1 – An additional flag "synchronizationUncertain" has been defined in Annex E; the use of the "synchronizationUncertain" flag is optional.

NOTE 2 – When a clock is in holdover, within holdover specification, the PTP clock may continue to advertise the last known leap second event. If there was no pending leap second event, then the PTP clock continues to advertise FALSE for the pending leap second fields (leap59 and leap61). If there was a pending leap second event, the PTP clock may choose to either advertise FALSE for the pending leap second fields immediately, or continues to advertise the leap second event. In the latter instance the PTP clock would clear the leap 59 and leap6 second event field(s) and adjust the UTC offset field at the appropriate time based on its local PTP time (i.e., the local PTP time's UTC timescale rolling over at UTC midnight) if the PTP clock is still in holdover, within holdover specification. When a clock is in holdover, out of holdover specifications, the PTP clock behaviour with respect to leap second event is implementation specific. It is recommended that PTP clock continue to advertise any upcoming leap second event as appropriate.

NOTE 3 – When a clock is in holdover, within holdover specification, the PTP clock may continue to advertise the last known UTC offset with UTC offset valid TRUE. If the last known UTC offset valid was FALSE then the PTP clock continues to advertise FALSE. If the last known UTC offset valid was TRUE then the PTP clock may choose to either advertise UTC offset valid FALSE immediately (freezing the UTC offset value), or continues to advertise the last known UTC offset with UTC offset valid TRUE. The UTC offset field may be updated as described in Note 2 above. When a clock is in holdover, out of holdover specifications, the PTP clock behaviour with respect to UTC offset is implementation specific.

NOTE 4 – Usage of currentUtcOffset from an Announce message, which indicates currentUtcOffsetValid as FALSE, may lead to wrong UTC time calculation.

Annex B

Options to establish the PTP topology with the Alternate BMCA

(This annex forms an integral part of this Recommendation.)

This PTP telecom profile defines an Alternate BMCA that allows using two main approaches to set up the topology of the phase/time synchronization network:

−   <u>Automatic topology establishment</u>: When configuring the localPriority attributes defined in this Recommendation to their default value, the PTP topology is established automatically by the Alternate BMCA based on the *Announce* messages exchanged by the PTP clocks. A synchronization tree with shortest paths to the T-GMs is built after this operation. In this mode, during failure events and topology reconfiguration, the Alternate BMCA will be run again and result in a new synchronization tree. This Alternate BMCA operation ensures that no timing loop will be created without requiring manual intervention or prior analysis of the network. The convergence time to the new PTP topology depends on the size of the network, and on the specific configuration of the PTP parameters.

−   <u>Manual network planning</u>: The use of the localPriority attributes defined in this Recommendation with different values than their default value allows building manually the synchronization network topology, in a similar way as synchronous digital hierarchy (SDH) networks are typically operated based on the synchronization status message (SSM). This option allows a full control on the actions during failure events and topology reconfiguration, based on the configured local priorities of the system. However, careful network planning is required prior to the deployment in order to avoid timing loops.

Annex C

Inclusion of an external phase/time input interface in a T-BC

(This annex forms an integral part of this Recommendation.)

This annex describes the model for inclusion of an external phase/time input interface in a T-BC, so that this external port can participate in the source selection. The high-level principles are introduced in this annex.

A virtual PTP port and a virtual E_{rbest} is associated to the external phase/time input (e.g., coming from a PRTC) of the T-BC, in order to allow this external interface to participate in the PTP protocol.

The following attributes are associated to the virtual PTP port:
–   clockClass;
–   clockAccuracy;
–   offsetScaledLogVariance;
–   localPriority.

The stepsRemoved attribute must be set to zero in the case a PRTC is connected to the external phase/time interface.

The grandmasterIdentity assigned to the virtual PTP port is the clockIdentity of the T-BC itself. The portNumber assigned to the virtual PTP port is set to a value different from the portNumber values already assigned to the T-BC PTP ports.

The values assigned to the virtual PTP port for other parameters used in the data set comparison algorithm are for further study.

NOTE 1 – The general case of T-BC with a phase/time external synchronization input different from PRTC is for further study.

NOTE 2 – If the external phase/time interface contains a time-of-day data channel for transmitting time and associated information, this information should be considered in deriving the values of the relevant PTP attributes of the virtual PTP port. The details of the time information to be transmitted are for further study. Initial descriptions can be found in Appendix III of [ITU-T G.8272].

Annex D

Path trace (optional)

(This annex forms an integral part of this Recommendation.)

In order to track the actual path of the PTP synchronization reference in the network, the Path trace option as per clause 16.2 in [IEEE 1588] can be optionally supported by the PTP clock compliant with this profile.

This feature is optional; however, if it is supported it is necessary that it be supported as described below.

As an example, this option can be used to support troubleshooting analysis in case of failures in the network.

It should be possible to configure a PTP clock so that the Path trace type length value (TLV) is not further forwarded by that clock (e.g., this could be required at the network administration interfaces).

NOTE 1 – There might be cases when not all PTP clocks in the network support the Path trace TLV. The expected behaviour is that in the case of an incoming Announce message carrying the Path trace TLV, this TLV is dropped by these nodes.

NOTE 2 – T-TCs in the path could add their own clockIdentity in the Path trace TLV.

Annex E

Synchronization uncertain indication (optional)

(This annex forms an integral part of this Recommendation.)

This annex is optional but, if implemented, it is necessary for the equipment to conform to requirements contained herein. When a PTP clock selects a new parent as a synchronization time source, the PTP port associated with that new parent is placed in the UNCALIBRATED state. This PTP port state indicates that the PTP clock is in the process of synchronizing to the time source. The duration and functionality of this state is implementation specific. During this period, the PTP clock may have large or fast changes in frequency and phase, and while it is desirable that the updated parent information be propagated downstream to allow the topology to settle, it may not be desirable for the downstream PTP clocks to use the timing information. Therefore, communicating to downstream PTP clocks about the UNCALIBRATED state would be beneficial.

The local synchronizationUncertain boolean, used with Announce messages transmitted from an egress port is FALSE except under the following conditions for which it shall be TRUE:

• the synchronizationUncertain flag of the Announce message received from the parent clock is TRUE; or

• the ingress port is in the UNCALIBRATED state; or

• implementation specific criteria.

When the synchronizationUncertain condition is TRUE then in the transmitted Announce message the flagField – octet 1, bit 6 is set to 1. Otherwise, when the synchronizationUncertain condition is FALSE, the bit is set to 0.

The default value for the synchronizationUncertain flag was picked so that the value transmitted out of a PTP clock that does not have the synchronizationUncertain functionality indicates that its timing information can be used. This allows a downstream clock that does support the functionality to use an upstream parent clock that does not support this functionality. The downstream clock considers the timing information from the upstream clock as usable and performs synchronization processing using this timing information. As this situation could lead to misinterpretation of the actual synchronization quality at the end of the network clock chain, it is not recommended to depend on this synchronizationUncertain indication unless all PTP clocks in the network support this functionality.

Annex F

Use of stepsRemoved to limit reference chain (optional)

(This annex forms an integral part of this Recommendation.)

The parameter stepsRemoved is defined in [IEEE1588] is used to indicate the distance between a clock and the grandmaster clock in the network. It was originally intended to be used as a helpful tool to detect cyclic paths that may occur in PTP systems. By default it is required that a clock not qualify any Announce messages where the stepsRemoved field is equal to, or greater than, 255 in order to ensure that rogue frames are extinguished.

This profile includes a default dataset member, maxStepsRemoved, that allows the operator to configure the value to less than 255. The value configured is typically the same in all clocks in the PTP domain. When configured, a clock would not qualify any Announce messages received where the stepsRemoved field in the ingress header matched or exceeded the maxStepsRemoved field. There would be two primary use cases for this configurability.

First, referring to [ITU-T G.8271.1] and [ITU-T G.8275] analysis has been performed to show that up to 20 clocks may be traversed between the grandmaster and slave while maintaining the proper network performance. If the operator wanted to ensure the network performance limit was not exceeded, or that the chain length was not exceeded, the operator may configure the value smaller (such as 20 or 21).

Second, if the operator does deploy PTP in a ring topology, the operator may configure the maxStepsRemoved parameter to a smaller value so that the clocks may more quickly identify rogue frames and take corrective action to extinguish them and update the topology.

Annex G

Monitoring a PTP MASTER port by a PTP PASSIVE port (optional)

(This annex forms an integral part of this Recommendation.)

This annex is optional but, if implemented, it is necessary for the equipment to conform to requirements contained herein.

A PTP clock must synchronize only to a PTP port of its parent clock that is in the MASTER state. The synchronization must be received on, and only on, the port of the PTP clock that is in the SLAVE state. However, in some instances it may be desirable for a PTP port in the PASSIVE state to receive time information from its peer, which is in the MASTER state.

When a PTP port is in the PASSIVE state, the PTP port may transmit Delay_Req messages with the alternateMasterFlag value set to FALSE. A PTP port that receives a Delay_Req message, if it is in the MASTER state, responds with a Delay_Resp message with alternateMasterFlag value to set to FALSE.

NOTE – The alternate master flag can be used in order to exchange PTP messages with ports in the PASSIVE state, including transmission of Delay_Req to acquire knowledge of the characteristics of the transmission path.

Appendix I

Considerations on the use of transparent clock

(This appendix does not form an integral part of this Recommendation.)

The integration of the transparent clock in this profile is considered of particular interest for applications such as 2-port type of devices.

For more complex topologies and multiport devices some careful analysis is recommended. In particular, some specific node configuration may be required if the operator wants to prevent multicast packets flooding the network.

Some options could be considered, e.g., by configuration of the T-TCs with insertion of a VLAN tag in the frames carrying PTP. In this case all T-TCs in the PTP communication path where this option is used should support this option. The last T-TC node would need to remove the VLAN tag. By using this option to connect the physical ports of the T-GM, T-BC, and T-TSCs through VLAN virtual connections across the T-TCs, the multicast flooding can be avoided. In this way the PTP port of a T-GM, T-BC or T-TSC would never process a VLAN tagged frame.

The related operational implications would need to be carefully considered.

Appendix II

Considerations on the transmission of Delay_Req messages

(This appendix does not form an integral part of this Recommendation.)

This appendix discusses the requirements defined in [IEEE 1588] for the transmission of *Delay_Req* messages when using the default uniform distribution defined in bullet 3 of clause 9.5.11.2 of [IEEE 1588]. This uniform distribution is not used in the PTP telecom profile defined in this Recommendation; a profile-specific distribution has been defined in clause 6.2.8.

The second dashed item of the requirements defined in clause 9.5.11.2 of [IEEE 1588] controls the variability of the times between successive *Delay_Req* messages. It is analogous to the corresponding requirement for the sending of *Sync* and *Announce* messages, given in clause 7.7.2.1 of [IEEE 1588]. However, a key difference is that, while the requirement for *Sync* messages applies to the population of inter-message intervals, the requirement for *Delay_Req* messages applies only to the mean of the population.

To be more precise, assume that a population of N inter-message intervals has been measured, and let T_j be the measured values, $j = 1, 2, \ldots, N$. The sample mean, m, is just the numerical average, i.e.,

$$m = \frac{1}{N} \sum_{j=1}^{N} T_j \tag{II.1}$$

Let T_{min} be the minimum *Delay Request* interval; it is equal to $2^{\text{portDS.logMinDelayReqInterval}}$ s. The second dashed item above states that the mean of the distribution must be greater than or equal to T_{min} with 90% or greater statistical confidence.

The statistical test for this is well-known, and is based on the fact that the distribution of m approaches a normal distribution as N becomes large (i.e., it is based on the central limit theorem). Let σ be the standard deviation of the distribution of the inter-message times, i.e., the distribution of the T_j. Let $z_{0.90}$ be the 90th percentile of the standard normal distribution; it is given by $z_{0.90} = 1.281$. Then, the probability that the true mean of the distribution exceeds the quantity

$$q_{0.1} = m - z_{0.90} \sqrt{\frac{\sigma}{N}} \tag{II.2}$$

is 0.9, i.e., 90%. The probability that the mean of the distribution is less than this value is 0.1. In addition, if σ is not known, the sample standard deviation, s, may be used in equation (II.2) and the Normal distribution is replaced by the Student-t distribution with $N - 1$ degrees of freedom. The sample standard deviation is given by:

$$s = \left[\frac{1}{N-1} \sum_{j=1}^{N} (T_j - m)^2 \right]^{1/2} \tag{II.3}$$

To meet the requirement, the quantity $q_{0.1}$ must exceed T_{min}. It is seen from equation (II.2) that $q_{0.1}$ approaches m as N approaches infinity. Since m converges to the mean of the distribution of inter-message times as N approaches infinity, the requirement can be met for sufficiently large N as long as the mean of the distribution exceeds T_{min}. The mean of the distribution must exceed T_{min}; the requirement cannot be met if the mean of the distribution is exactly equal to T_{min} or less than T_{min}.

If it is chosen to comply with the requirement of the third dashed item of clause 9.5.11.2 of [IEEE 1588], one way of meeting this requirement is to increase the upper end of the probability

distribution by 10%. If this is done, the transmission times are selected such that the interval between successive *Delay_Req* messages is taken from a uniform distribution over the interval between 0 and $2.2T_{min}$. A new random value for the transmission interval is computed for each message transmitted. When computing the mean *Delay_Req* interval from measured samples to check if it exceeds T_{min} with 90% or greater statistical confidence (if the third dashed item is used), the number of measured samples N must be at least 1000. The granularity of the distribution must be less than or equal to 1/16 *Sync* interval.

If it is chosen to meet the requirement of the fourth dashed item of clause 9.5.11.2 of [IEEE 1588], a *Delay_Req* message is transmitted as soon as possible after receipt of a *Sync* message, subject to not violating the second dashed item.

Appendix III

Considerations on the choice of the PTP Ethernet multicast destination address

(This appendix does not form an integral part of this Recommendation.)

This PTP profile supports both the non-forwardable multicast address 01-80-C2-00-00-0E and forwardable multicast address 01-1B-19-00-00-00 when the PTP mapping defined in Annex F of [IEEE 1588] is used.

The Ethernet multicast address to be used depends on the operator policy; further considerations are provided hereafter.

Layer 2 bridging function associated with the PTP port of a T-BC or T-TC should not forward any frame with destination MAC address 01-1B-19-00-00-00; this could be done by properly provisioning this multicast address in the filtering database.

Option 1 – Use of the non-forwardable multicast address 01-80-C2-00-00-0E

Some network operators consider that the PTP messages must never be forwarded through PTP-unaware network equipment.

The use of the non-forwardable multicast address 01-80-C2-00-00-0E guarantees this property most of the time (exceptions exist for some older Ethernet equipment).

Therefore, in the case of network equipment misconfiguration (e.g., if the PTP functions are not enabled in PTP-aware network equipment), the use of this multicast address prevents incorrect distribution of synchronization, since the PTP messages will be blocked by the PTP-unaware network equipment.

Option 2 – Use of the forwardable multicast address 01-1B-19-00-00-00

Some network operators consider that using a forwardable multicast address is more flexible and that it is preferable to forward the PTP messages to keep the synchronization link running in case some equipment is misconfigured as non PTP nodes, although there are potentially risks of performance degradation. The network management system (NMS) will easily find the misconfiguration and will send alarms.

However, it is possible to block the PTP messages by properly provisioning this multicast address in the filtering database of each Ethernet equipment.

Appendix IV

Considerations on the use of priority2

(This appendix does not form an integral part of this Recommendation.)

The PTP attribute priority2 is configurable in this profile. In some special circumstances, the use of the priority2 attribute can simplify the network management. This appendix describes two use cases; other possible cases are for further study.

Case 1

Operators can configure the PTP attribute priority2 to make all of the T-BCs either traceable to one T-GM, or traceable to two different T-GMs at the same time.

G.8275.1-Y.1369.1(14)_FIV.1
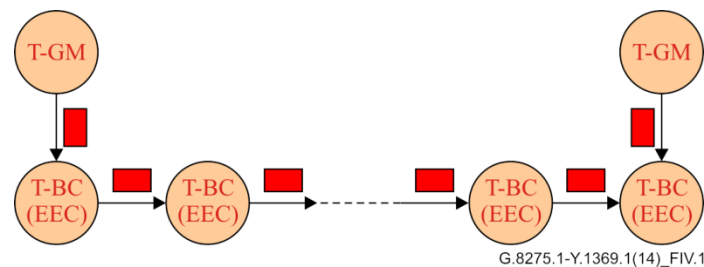
Figure IV.1 – Use of priority2 with two T-GMs in the network

For example, in Figure IV.1, if all other PTP attributes of the two T-GMs are the same, and the two T-GMs are configured with the same priority2 value, each T-BC will select the T-GM with the shortest path. If the two T-GMs are configured with different priority2 values, all of the T-BCs will synchronize to the T-GM with the smallest priority2 value.

Case 2

Operators can configure the PTP attribute priority2 to prevent the T-BCs of an upstream network from synchronizing with the T-BCs of a downstream network when the T-GM is in failure.

G.8275.1-Y.1369.1(14)_FIV.2
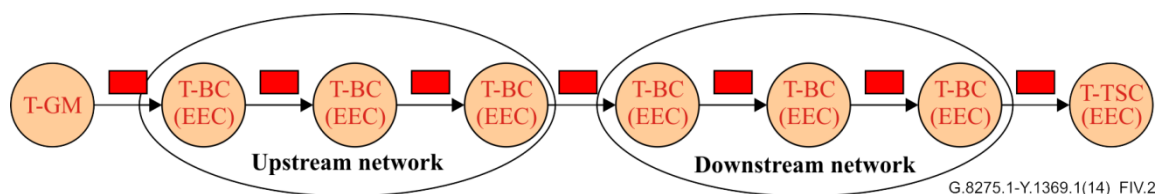
Figure IV.2 – Use of priority2 with T-BCs of different network layers

For example, in Figure IV.2, if all other PTP attributes of all of the T-BCs are the same, and the PTP attribute priority2 of all of T-BCs are configured with the same value, then when the T-GM is in failure, the T-BCs in the upstream network can synchronize with the T-BCs in the downstream network, depending on the clockIdentity values of all of the T-BCs. If the T-BCs in the upstream network are configured with a smaller priority2 value than the T-BCs in the downstream network then, when the T-GM is in failure, the T-BCs in the downstream network will synchronize to the T-BCs in the upstream network.

Appendix V

Description of PTP clock states and associated contents of Announce messages

(This appendix does not form an integral part of this Recommendation.)

V.1 Purpose of the appendix

This appendix provides information related to possible T-GM and T-BC clock states. The intention of the clock state information is to provide a high-level indication of the operational status of the entire clock as opposed to just individual PTP ports. It provides a mapping between the clock states and PTP port states as defined in [IEEE 1588]. In addition, it provides a table showing the content of the *Announce* message fields that will occur in the various clock states.

The Acquiring clock state, if included in an implementation, allows a T-GM or a T-BC to delay the distribution of GM information transmitted by the clock. The purpose of this Acquiring clock state is to allow a T-GM or a T-BC some time to establish a timescale with acceptable accuracy before using it for the clock's node time.

NOTE – The procedures defined within this appendix for the Acquiring clock state are not compliant to the procedures of [IEEE 1588] and the delay introduced by this state can impact the overall settling time during PTP topology rearrangements.

Network deployments including clocks using the procedures of this Appendix are under operator responsibility.

V.2 Description of the states

– Free-Run state

> The PTP clock has never been synchronized to a time source and is not in the process of synchronizing to a time source.

> As it relates to the PTP port state defined in [IEEE 1588], a clock is in Free-Run state if there are no PTP ports in: MASTER, PRE-MASTER, PASSIVE, UNCALIBRATED or SLAVE states.

– Acquiring state

> The PTP clock is in process of synchronizing to a time source. The duration and functionality of this state is implementation specific. This state is not required in an implementation.

> As it relates to the PTP port state defined in [IEEE 1588], a clock is in Acquiring state if there is a PTP port in UNCALIBRATED state.

– Locked state

> The PTP clock is synchronized to a time source and is within some internal acceptable accuracy.

> As it relates to the PTP port state defined in [IEEE 1588], a clock is in Locked state if there is a PTP port in SLAVE state.

– Holdover-In-Specification state

> The PTP clock is no longer synchronized to a time source and is using information obtained while it was previously synchronized or other information sources were still available, to maintain performance within desired specification. The node may be relying solely on its own facilities for holdover or may use something like a frequency input from the network to achieve a holdover of time and/or phase.

As it relates to the PTP port state defined in [IEEE 1588], a clock is in Holdover-In-Specification state if there are no PTP ports in: INITIALIZING, LISTENING, UNCALIBRATED or SLAVE states, and performance is within desired specification.

– Holdover-Out-Of-Specification state

The PTP clock is no longer synchronized to a time source and, while it may be using information obtained while it was previously synchronized or other information sources were still available, it is unable to maintain performance within desired specification.

As it relates to the PTP port state defined in [IEEE 1588], a clock is in Holdover-Of-Out-Specification state if there are no PTP ports in: INITIALIZING, LISTENING, UNCALIBRATED or SLAVE states, and performance is not within desired specification.

V.3 Example of mapping between PTP port states and PTP clock states for a 3-port T-BC

Table V.1 – PTP port state vs clock state mapping

	Port state			Clock state	
Trigger event	**Port 1**	**Port 2**	**Port 3**		**Notes**
Power up of PTP	INITIALIZING	INITIALIZING	INITIALIZING	Free-Run	No port in MASTER, PASSIVE, UNCALIBRATED, or SLAVE
Clock completes initialization	LISTENING	LISTENING	LISTENING	Free-Run	No port in MASTER, PASSIVE, UNCALIBRATED, or SLAVE
Qualified *Announce* received from foreign master on port P1	UNCALIBRATED	LISTENING	LISTENING	Acquiring	A port is in UNCALIBRATED state
ANNOUNCE_RECEIPT_TIME OUT_EXPIRES event on ports P2 and P3	UNCALIBRATED	MASTER	MASTER	Acquiring	A port is in UNCALIBRATED state
Calibration finished on port P1	SLAVE	MASTER	MASTER	Locked	A Slave port exists on the node
ANNOUNCE_RECEIPT_TIME OUT_EXPIRES event on port P1	MASTER	MASTER	MASTER	Holdover-In-Specification	Start holdover timer No port in SLAVE, UNCALIBRATED, LISTENING, or INITIALIZING
Holdover timer expires	MASTER	MASTER	MASTER	Holdover-Out-Of-Specification	Holdover timer expired and no port in SLAVE, UNCALIBRATED, LISTENING, or INITIALIZING
Port P3 receives qualified *Announce* with clockClass = 7	MASTER	MASTER	UNCALIBRATED	Acquiring	A port is in UNCALIBRATED state
Calibration finished on port P3	MASTER	MASTER	SLAVE	Locked	A Slave port exists on the node
Port P1 receives qualified *Announce* with clockClass = 6	UNCALIBRATED	MASTER	PRE_MASTER	Acquiring	A port is in UNCALIBRATED state
QUALIFICATION_TIMEOUT _EXPIRES event on port P3	UNCALIBRATED	MASTER	MASTER	Acquiring	A port is in UNCALIBRATED state
Calibration finished on port P1	SLAVE	MASTER	MASTER	Locked	A Slave port exists on the node

V.4 T-GM Announce message contents based on the internal PTP clock states

Table V.2 – T-GM Announce message contents

Announce message fields	Free-Run state	Acquiring state	Locked state	Holdover-In-Specification state	Holdover-Out-Of-Specification state
sourcePortIdentity (header.sourcePortIdentity)	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number
leap61 (header.flagField)	FALSE	From Time Source	From Time Source	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation specific] (Note 2)
leap59 (header.flagField)	FALSE	From Time Source	From Time Source	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation specific] (Note 2)
currentUtcOffsetValid (header.flagField)	FALSE	TRUE/FALSE [Implementation Specific]	TRUE	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation Specific] (Note 2)
ptpTimescale (header.flagField)	TRUE	TRUE	TRUE	TRUE	TRUE
timeTraceable (header.flagField)	FALSE	TRUE	TRUE	TRUE	FALSE
frequencyTraceable (header.flagField)	FALSE	TRUE/FALSE based on Frequency Source lock	TRUE	TRUE/FALSE based on Frequency Source lock	TRUE/FALSE based on Frequency Source lock
currentUtcOffset	As per PTP	Based on input reference UTC offset	Based on input reference UTC offset	Last known UTC offset (Note 2)	Last known UTC offset (Note 2)
grandmasterPriority1	128 (default)	128 (default)	128 (default)	128 (default)	128 (default)
grandmasterClockQuality.clockClass	248	Implementation specific, generally previous state 7/140/150/160/248	6	7	140/150/160

Table V.2 – T-GM Announce message contents

Announce message fields	Free-Run state	Acquiring state	Locked state	Holdover-In-Specification state	Holdover-Out-Of-Specification state
grandmasterClockQuality.clockAccuracy	Unknown (0xFE)	Unknown (0xFE)	0x21, 0x20	Unknown (0xFE)	Unknown (0xFE)
grandmasterClockQuality.offsetScaledLogVariance	0xFFFF (default)	0xFFFF (default)	0x4E5D, 0x4B32	0xFFFF (default)	0xFFFF (default)
grandmasterPriority2	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM
grandmasterIdentity	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM
stepsRemoved	0	0	0	0	0
timeSource	INT_OSC (0xA0)	INT_OSC (0xA0)	As per PTP	INT_OSC (0xA0)	INT_OSC (0xA0)
synchronizationUncertain	TRUE (Note 3)	TRUE	FALSE (Note 3)	FALSE (Note 3)	TRUE (Note 3)
NOTE 1 – Time Properties (leap61, leap59, currentUtcOffsetValid, currentUtcOffset) can be obtained from time source (GNSS or TOD) or user configuration. NOTE 2 – Refer to Table A.8. NOTE 3 – Or as defined in Annex E.					

Table V.2 – T-GM Announce message contents

Announce message fields	Free-Run state	Acquiring state	Locked state	Holdover-In-Specification state	Holdover-Out-Of-Specification State
sourcePortIdentity (header.sourcePortIdentity)	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number	Local clockId of the T-GM + Port Number
leap61 (header.flagField)	FALSE	From Time Source	From Time Source	FALSE	FALSE
leap59 (header.flagField)	FALSE	From Time Source	From Time Source	FALSE	FALSE

currentUtcOffsetValid (header.flagField)	FALSE	TRUE/FALSE [Implementation Specific]	TRUE	TRUE	TRUE/FALSE [Implementation Specific]
ptpTimescale (header.flagField)	TRUE	TRUE	TRUE	TRUE	TRUE
timeTraceable (header.flagField)	FALSE	TRUE	TRUE	TRUE	FALSE
frequencyTraceable (header.flagField)	FALSE	TRUE/FALSE based on Frequency Source lock	TRUE	TRUE/FALSE based on Frequency Source lock	TRUE/FALSE based on Frequency Source lock
currentUtcOffset	35	Based on input reference UTC offset	Based on input reference UTC offset	Last known UTC offset	Last known UTC offset
grandmasterPriority1	128 (default)	128 (default)	128 (default)	128 (default)	128 (default)
grandmasterClockQuality.clockClass	248	Implementation specific, generally previous state 7/140/150/160/248	6	7	140/150/160
grandmasterClockQuality.clockAccuracy	Unknown (0xFE)	Unknown (0xFE)	Time is accurate within 100 ns (0x21)	Unknown (0xFE)	Unknown (0xFE)
grandmasterClockQuality.offsetScaledLogVariance	0xFFFF (default)	0xFFFF (default)	0x4E5D	0xFFFF (default)	0xFFFF (default)
grandmasterPriority2	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM

grandmasterIdentity	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM
stepsRemoved	0	0	0	0	0
timeSource	INT_OSC (0xA0)	INT_OSC (0xA0)	As per PTP	INT_OSC (0xA0)	INT_OSC (0xA0)

V.5   T-BC Announce message contents based on the internal PTP clock states

<div align="center">

Table V.3 – T-BC Announce message contents

</div>

Announce message fields	Free-Run state	Acquiring state	Locked state	Holdover-In-Specification state	Holdover-Out-Of-Specification state
sourcePortIdentity (header.sourcePortIdentity)	Local clockId of the T-BC + Port Number	Local clockId of the T-BC + Port Number	Local clockId of the T-BC + Port Number	Local clockId of the T-BC + Port Number	Local clockId of the T-BC + Port Number
leap61 (header.flagField)	FALSE	(Note 1)	(Note 1)	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation specific] (Note 2)
leap59 (header.flagField)	FALSE	(Note 1)	(Note 1)	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation specific] (Note 2)
currentUtcOffsetValid (header.flagField)	FALSE	TRUE	(Note 1)	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation Specific] (Note 2)
ptpTimescale (header.flagField)	TRUE	TRUE	(Note 1)	TRUE	TRUE
timeTraceable (header.flagField)	FALSE	TRUE	(Note 1)	TRUE	FALSE
frequencyTraceable (header.flagField)	FALSE	TRUE/FALSE based on Frequency Source lock	(Note 1)	TRUE/FALSE based on Frequency Source lock	TRUE/FALSE based on Frequency Source lock
currentUtcOffset	As per PTP	Last known UTC offset	(Note 1)	Last known UTC offset	Last known UTC offset (Note 2)
grandmasterPriority1	128 (default)	128 (default)	(Note 1)	128 (default)	128 (default)
grandmasterClockQuality.clockClass	248	Implementation specific, generally previous state.	(Note 1)	135	165

Table V.3 – T-BC Announce message contents

Announce message fields	Free-Run state	Acquiring state	Locked state	Holdover-In-Specification state	Holdover-Out-Of-Specification state
		135/165/248			
grandmasterClockQuality.clockAccuracy	Unknown (0xFE)	Unknown (0xFE)	(Note 1)	Unknown (0xFE)	Unknown (0xFE)
grandmasterClockQuality.offsetScaledLogVariance	0xFFFF (default)	0xFFFF (default)	(Note 1)	0xFFFF (default)	0xFFFF (default)
grandmasterPriority2	Configured priority2 of the T-BC	Configured priority2 of the T-BC	(Note 1)	Configured priority2 of the T-BC	Configured priority2 of the T-BC
grandmasterIdentity	Local clockId of the T-BC	Local clockId of the T-BC	(Note 1)	Local clockId of the T-BC	Local clockId of the T-BC
stepsRemoved	0	0	Received stepsRemoved +1	0	0
timeSource	INT_OSC (0xA0)	INT_OSC (0xA0)	(Note 1)	INT_OSC (0xA0)	INT_OSC (0xA0)
synchronizationUncertain	(Note 4)	TRUE	(Note 4)	(Note 4)	(Note 4)

NOTE 1 – The value sent in the *Announce* message corresponds to the value of the current grandmaster or Time interface (as per G.8272 Appendix III) in case T-BC has selected a virtual port as best master.

NOTE 2 – Refer to Table A.8.

NOTE 3 – Valid UTC Offset is one advertised by master with currentUtcOffsetValid value TRUE. In case there is no such value available, either default initializing UTC offset or one advertised by master with currentUtcOffsetValid as false can be used.

NOTE 4 – The value sent in the Announce message corresponds to the value received from the current parent clock or as defined in Annex E.

					[Implementation Specific]
ptpTimescale (header.flagField)	TRUE	TRUE	(Note)	TRUE	TRUE
timeTraceable (header.flagField)	FALSE	TRUE	(Note)	TRUE	FALSE
frequencyTraceable (header.flagField)	FALSE	TRUE /FALSE based on Frequency Source lock	(Note)	TRUE /FALSE based on Frequency Source lock	TRUE /FALSE based on Frequency Source lock
currentUtcOffset	35	Last known UTC offset	(Note)	Last known UTC offset	Last known UTC offset
grandmasterPriority1	128 (default)	128 (default)	(Note)	128 (default)	128 (default)
grandmasterClockQuality.clockClass	248	Implementation specific, generally previous state. 135/165/248	(Note)	135	165
grandmasterClockQuality.clockAccuracy	Unknown (0xFE)	Unknown (0xFE)	(Note)	Unknown (0xFE)	Unknown (0xFE)
grandmasterClockQuality.offsetScaledLogVariance	0xFFFF (default)	0xFFFF (default)	(Note)	0xFFFF (default)	0xFFFF (default)
grandmasterPriority2	Configured priority2 of the T-BC	Configured priority2 of the T-BC	(Note)	Configured priority2 of the T-BC	Configured priority2 of the T-BC
grandmasterIdentity	Local clockId of the T-BC	Local clockId of the T-BC	(Note)	Local clockId of the T-BC	Local clockId of the T-BC
stepsRemoved	0	0	Received stepsRemoved +1	0	0
timeSource	INT_OSC (0xA0)	INT_OSC (0xA0)	(Note)	INT_OSC (0xA0)	INT_OSC (0xA0)

NOTE – The value sent in the *Announce* message corresponds to the value of the current GM.

Appendix VI

Operations over link aggregation

(This appendix does not form an integral part of this Recommendation.)

When two devices embedding PTP clocks compliant with this profile are connected via a link aggregation (LAG) as defined in [b-IEEE 802.1AX], each physical link should be accessed directly to transmit PTP messages, bypassing the LAG. This method prevents potential asymmetries that may be present when the forward and reverse paths are delivered over different links belonging to the LAG.

Alternative solutions taking advantage of some LAG features exist, such as the bidirectional congruity as defined by [b-IEEE 802.1AX]. These solutions are for further study.

For the scenarios currently considered, the insertion of a VLAN tag in the frames carrying PTP messages is not allowed. However, the bidirectional congruity alternative solution can be applied to untagged PTP frames by assigning a conversation ID equal to zero to a given physical link.

Appendix VII

Relationship between clockClass and holdover specification

(This appendix does not form an integral part of this Recommendation.)

The clockClass values that are used in this profile are described in Table 2. The values may be divided into four different categories:

1) T-GM locked to a PRTC or ePRTC;

2) T-GM or T-BC in holdover, within holdover specification;

3) T-GM or T-BC in holdover, outside of holdover specification;

4) Slave clock, or clock that has not been synchronized.

A short footnote (Note 1 of clause 6.4) refers to Appendix V of [ITU-T G.8271.1] for more information on the meaning of "in holdover, within holdover specification" and "in holdover, out of holdover specification". That appendix describes possible budget models for the synchronization performance. The exact model depends on the operator's network and design parameters, but each budget is broken down into several components:

1) PRTC/T-GM allocation;

2) Random time error from noise accumulation through the network (dTE);

3) Node asymmetry (cTE, the sum of the asymmetry of all the nodes in the system);

4) Link asymmetry (cTE, the sum of the asymmetry of all the links in the system);

5) Holdover budget;

6) End application budget.

Table V.1 of [ITU-T G.8271.1] shows that for one example budget, 400 ns may be allocated to holdover within the network (this is termed failure scenario (b) in the table). The operator may have different budget allocations, depending on their deployment scenario. The 400 ns holdover budget is allocated to the entire synchronization chain, and not to an individual clock.

The intended operation of the T-GM is, therefore, as follows:

– When the T-GM is synchronised to a PRTC locked to GNSS, it outputs clockClass 6.

– If the PRTC loses its connection to GNSS, it enters holdover. The T-GM should degrade the advertised clockClass to indicate "in holdover, but within holdover specification" (clockClass 7).

– The T-GM estimates when the holdover budget will potentially be exceeded. Factors to consider include the known quality of any external frequency support (e.g., SyncE QL), temperature variations, and/or the quality of the internal oscillator.

– When the T-GM considers that the clock is out of holdover specification (i.e., it is now estimated to have drifted by more than the holdover budget), the T-GM will advertise a clockClass of 140, 150 or 160.

In the event of a network failure, where the T-GM is disconnected from the synchronization chain, a T-BC will take over as the grandmaster of the chain. That T-BC will be operating in holdover. The clockClass that the T-BC is allowed to advertise depends on the clockClass of the T-GM to which it was synchronized prior to losing connectivity.

For example, if the T-BC was synchronized to a T-GM of clockClass 6, none of the holdover budget will have been consumed, and therefore the T-BC may use a clockClass indicating "within holdover specification" (e.g., clockClass 135). This value is chosen to be higher than that of a T-GM that is out of holdover specification, since the T-BC is likely to have more accurate time

because it has been locked to a traceable time source more recently. Therefore, if the two clocks (a T-BC in holdover, within holdover specification and a T-GM in holdover, but out of holdover specification) are compared in the Alternate BMCA operation of a subsequent clock, the subsequent clock will synchronize to the T-BC that is within holdover specification instead of a T-GM that is out of holdover specification.

In another example, if the T-BC was synchronized to a T-GM indicating that the T-GM is in holdover but out of holdover specification (e.g., parentDS clockClass 140, 150 or 160), the T-BC should also use a clockClass indicating "out of holdover specification" (e.g., defaultDS clockClass 165). This is because the T-GM was indicating that, in its estimation, the holdover budget has already been consumed.

In another example, if the T-BC was synchronized to another T-BC, and the other T-BC indicates that it is in holdover but out of holdover specification (e.g., parentDS clockClass 165), the original T-BC should also use a clockClass indicating "out of holdover specification" (e.g., defaultDS clockClass 165). This is because the other T-BC was indicating that, in its estimation, the holdover budget has already been consumed.

In a final example, if the T-BC was synchronized to a T-GM or another T-BC that was already in holdover but still within the holdover specification, the original T-BC could indicate "within holdover specification". However, some of the holdover budget will have already been consumed by the T-GM or T-BC. If it is not known how much of the budget is left, the T-BC should indicate "out of holdover specification".

NOTE – When the term clockClass is used with respect to the property of the individual PTP clock (T-GM, T-BC, T-TSC) it is referring to data set member defaultDS.clockQuality.clockClass. ~~The clockClass values that are used in this profile are described in Table 2. The values may be divided into four different categories:~~

1) ~~T-GM locked to a PRTC or ePRTC;~~

2) ~~T-GM or T-BC in holdover, within holdover specification;~~

3) ~~T-GM or T-BC in holdover, outside of holdover specification;~~

4) ~~Slave clock, or clock that has not been synchronized.~~

~~A short footnote (Note 1 of clause 6.4) refers to Appendix V of [ITU-T G.8271.1] for more information on the meaning of "in holdover, within holdover specification" and "in holdover, out of holdover specification". That appendix describes possible budget models for the synchronization performance. The exact model depends on the operator's network and design parameters, but each budget is broken down into several components:~~

1) ~~PRTC/T-GM allocation;~~

2) ~~Random time error from noise accumulation through the network (dTE);~~

3) ~~Node asymmetry (cTE, the sum of the asymmetry of all the nodes in the system);~~

4) ~~Link asymmetry (cTE, the sum of the asymmetry of all the links in the system);~~

5) ~~Holdover budget;~~

6) ~~End application budget.~~

~~Table V.1 of [ITU-T G.8271.1] shows that for one example budget, 400 ns may be allocated to holdover within the network (this is termed failure scenario (b) in the table). The operator may have different budget allocations, depending on their deployment scenario. The 400 ns holdover budget is allocated to the entire synchronization chain, and not to an individual clock.~~

~~The intended operation of the T-GM is, therefore, as follows:~~

• ~~When the T-GM is synchronised to a PRTC locked to GNSS, it outputs clockClass 6.~~

- If the PRTC loses its connection to GNSS, it enters holdover. The T-GM should degrade the advertised clockClass to indicate "in holdover, but within holdover specification" (clockClass 7).
- The T-GM estimates when the holdover budget will potentially be exceeded. Factors to consider include the known quality of any external frequency support (e.g., SyncE QL), temperature variations, and/or the quality of the internal oscillator.
- When the T-GM considers that the clock is out of holdover specification (i.e., it is now estimated to have drifted by more than the holdover budget), the T-GM will advertise a clockClass of 140, 150 or 160.

In the event of a network failure, where the T-GM is disconnected from the synchronization chain, a T-BC will take over as the grandmaster of the chain. That T-BC will be operating in holdover. The clockClass that the T-BC is allowed to advertise depends on the clockClass of the T-GM to which it was synchronized prior to losing connectivity.

For example, if the T-BC was synchronized to a T-GM of clockClass 6, none of the holdover budget will have been consumed, and therefore the T-BC may use a clockClass indicating "within holdover specification" (e.g., clockClass 135). This value is chosen to be higher than that of a T-GM that is out of holdover specification, since the T-BC is likely to have more accurate time because it has been locked to a traceable time source more recently. Therefore, if the two clocks (a T-BC in holdover, within holdover specification and a T-GM in holdover, but out of holdover specification) are compared in the Alternate BMCA operation of a subsequent clock, the subsequent clock will synchronize to the T-BC that is within holdover specification instead of a T-GM that is out of holdover specification.

In another example, if the T-BC was synchronized to a T-GM indicating that it is in holdover but out of holdover specification (e.g., clockClass 140, 150 or 160), the T-BC should also use a clockClass indicating "out of holdover specification" (e.g., clockClass 165). This is because the T-GM was indicating that, in its estimation, the holdover budget has already been consumed.

In a final example, if the T-BC was synchronized to a T-GM that was already in holdover but still within the holdover specification, the T-BC could indicate "within holdover specification". However, some of the holdover budget will have already been consumed by the T-GM. If it is not known how much of the budget is left, the T-BC should indicate "out of holdover specification".

Appendix VIII

Considerations on a T-TSC connected to an end application

(This appendix does not form an integral part of this Recommendation.)

The default T-TSC clockclass 255 implies that the T-TSC will always lock to an external PTP reference when available.

The actual synchronization source ultimately used by the end application depends on the applicable synchronization needs. This process is out of the scope of this recommendation.

As an example, the decision to use the PTP reference that has been selected by the T-TSC (e.g., instead of entering holdover), could depend on the actual clockQuality, frequencyTraceable flag, timeTraceable flag, and synchronizationUncertain flag associated to the external PTP reference. Additional aspects as related to performance monitoring of the external reference might also be considered. This is implementation specific.

As an example, when it is required to meet the network timing requirements as per e.g., [ITU-T G.8271.1], it would be necessary that the external PTP reference has clockClass 6, 7 or 135 and that the timeTraceable flag is TRUE in order to be used by the end application. When this condition is not met, the end application may decide to enter holdover (either using the internal oscillator or driven by SyncE).

Appendix IX

Calculation of offsetScaledLogVariance for T-GM timed by PRTC or ePRTC

(This appendix does not form an integral part of this Recommendation.)

IX.1 Observation interval and TDEV noise generation

The offsetScaledLogVariance is an offset, scaled representation of the PTP variance (PTPVAR). PTPVAR is described in clause 7.6.3 of [IEEE 1588]; it is equal to Allan variance multiplied by $\tau^2/3$, where τ is the observation interval. PTP variance is therefore not a single value; it is a function of observation interval. Clause 7.6.3 of [IEEE 1588] specifies that the observation interval τ shall be the value defined in the applicable PTP profile. Clause 7.6.3 of [IEEE 1588] refers to τ as the sampling period. However, comparison of the equations in clause 7.6.3.2 of [IEEE 1588] with the equations for Allan variance in clause II.1 of [ITU-T G.810] indicates that τ in clause 7.6.3 of [IEEE 1588] is the observation interval of [ITU-T G.810], and not the sampling interval τ_0.

The offsetScaledLogVariance, i.e., defaultDS.clockQuality.offsetScaledLogVariance, is a clock attribute used in the BMCA. As indicated in clause 7.6.3.5 of [IEEE 1588], it is "an estimate of the variations of the local clock from a linear timescale when it is not synchronized to another clock using the protocol" (quoted text is from [IEEE 1588]; the "protocol" refers to the PTP protocol). Since a clock is not synchronized to another clock via PTP when it is grandmaster, the offsetScaledLogVariance should represent the long-term noise that the clock generates, because it is this noise that is generated if the clock is grandmaster. Therefore, the observation interval should be the longest interval over which noise generation for the clock in question is specified.

For a T-GM timed by a PRTC, i.e., a clock that meets the requirements of [ITU-T G.8272], the longest observation interval for which noise generation TDEV is specified is 10000 s (see Figure 2 of [ITU-T G.8272]). For this interval, TDEV is 30 ns. The specified noise type for intervals ranging from 1000 s to 10000 s is flicker phase modulation (FPM), with TDEV equal to 30 ns in this range. For a T-GM timed by an ePRTC, the longest observation interval for which noise generation TDEV is specified is 10^6 s. For this interval, TDEV is 10 ns. The specified noise type for intervals ranging from 3×10^5 s to 10^6 s is FPM, with TDEV equal to 10 ns in this range.

The value of the observation interval is not used directly in the PTP protocol, and is not carried in any PTP messages. It is used only in evaluating PTP variance.

The above values of observation interval and corresponding noise generation TDEV, for the PRTC and ePRTC, are summarized in Table IX.1.

Table IX.1 – Observation intervals, and corresponding noise generation TDEV values and noise type, for T-GM timed by PRTC and T-GM timed by ePRTC

Clock that T-GM is timed by	Observation interval (τ) for offsetScaledLogVariance (s)	$n = \tau / \tau_0$ (see clause IX.2 below)	Noise type	TDEV (ns)
PRTC	1000 – 10000	1.6×10^4 to 1.6×10^5	FPM	30
ePRTC	300 000 – 1 000 000	4.8×10^6 to 1.6×10^7	FPM	10

IX.2 Computation of PTP variance from TDEV

The next step is to compute PTP variance from the TDEV values given in the previous clause. Since PTP variance is equal to $\tau^2/3$ multiplied by Allan variance, and time variance (TVAR) is equal to $\tau^2/3$ multiplied by modified Allan variance, the ratio of TVAR to PTP variance is equal to the ratio of modified Allan variance (MVAR) to Allan variance. This latter ratio is discussed and computed for various noise types in section A.6 of [b-Sullivan]. The results given there are based on [b-Walls]

and [b-Lesage]. In addition, the relations between power spectral density (PSD) and Allan variance are given in Table 5.4 of [b-Bregni], and between PSD and modified Allan variance in Table 5.5 of [b-Bregni] (when using relations between PSD and various time-domain stability parameters, it is important to take note of whether the PSD is of time ($S_x(f)$) or of frequency ($S_y(f)$)).

Let n be the ratio of observation interval τ to sampling interval τ_0, i.e., $\tau = n\tau_0$. In general, the ratio of MVAR to AVAR, denoted $R(n)$, depends on n, though at least for the noise types white phase modulation (WPM), flicker FPM, white frequency modulation (WFM), flicker frequency modulation (FFM), and random-walk frequency modulation (RWFM), it approaches an asymptotic value for large n. In addition, for the case of FPM $R(n)$ depends on the measurement system bandwidth (for WPM, both AVAR and MVAR individually depend on measurement system bandwidth, though their ratio does not). Since time synchronization information from whichever clock is selected as grandmaster is transported via Sync messages, the sampling interval τ_0 can be taken equal to the Sync interval. The actual successive Sync intervals vary with time, as allowed by clause 7.7.2.1 of [IEEE 1588]; for simplicity, we may take τ_0 equal to the mean Sync interval. This is 1/16 s in [ITU-T G.8275.1]. Then, using the observation interval values in Table IX.1 above, the corresponding values of n range from 1.6×10^4 to 1.6×10^5 for a T-GM timed by a PRTC, and from 4.8×10^5 to 1.6×10^5 for a T-GM timed by an ePRTC. The values of n are also summarized in Table 1 above.

From Table IX.1, it is seen that the range of n is different for the PRTC and ePRTC. This means that, even though the noise type in the ranges of interest for these clocks is the same, $R(n)$ will be different, and TVAR for each clock will be adjusted by a different factor to obtain PTPVAR. However, the PRTC and ePRTC stability (as well as the stability of other clocks used in telecommunications) are specified using TDEV (i.e., square root of TVAR), and not using PTPDEV or PTPVAR. It therefore would be desirable to adjust TVAR for the PRTC and ePRTC by the same factor. In previous work, in which TVAR for the PRTC was compared to TVAR for a T-BC timed by SyncE, $R(n)$ was equal to 0.787. This value is used here for convenience, for both the PRTC and ePRTC.

With the above assumption, PTPVAR for the PRTC is given by:

$$\text{PTPVAR (PRTC)} = \frac{\text{TVAR}}{R(n)} = \frac{(30 \times 10^{-9})^2 \text{ s}^2}{0.787} = 1.144 \times 10^{-15} \text{ s}^2 \tag{IX.1}$$

and PTPVAR for the ePRTC is given by:

$$\text{PTPVAR (ePRTC)} = \frac{\text{TVAR}}{R(n)} = \frac{(10 \times 10^{-9})^2 \text{ s}^2}{0.787} = 1.271 \times 10^{-16} \text{ s}^2 \tag{IX.2}$$

IX.3   Computation of offsetScaledLogVariance from PTP variance

offsetScaledLogVariance is now computed from the PTPVAR results of the previous clause, using the procedure described in clause 7.6.3.3 of [IEEE 1588]. This procedure is:

a)   The logarithm to base 2 of PTPVAR expressed in units of s^2 is computed;

b)   The result of (a) is multiplied by 2^8 to produce a scaled value;

c)   The scaled value is modified per the hysteresis specification of clause 7.6.3.3 of [IEEE 1588]. (This step is not needed here, because offsetScaledLogVariance is being computed from a specification, rather than from real-time measurements.);

d)   The result of (c) is represented as a 2s complement Integer16 (i.e., it is represented as a signed integer, where negative values are represented in 2s complement form (since PTPVAR is less than 1 s^2 in almost all cases of practical interest, and certainly in the cases described in the previous clause, the result of (c) will almost always be negative));

e)   The value 0x8000 is added to the result of (d), and any overflow is ignored;

f)   The result of (e) is cast as an Integer16. This result, which may also be expressed in writing in hexadecimal form, is offsetScaledLogVariance.

IX.3.1 Computation of offsetScaledLogVariance for a T-GM timed by a PRTC

From Eq. (IX.1), PTPVAR = 1.144×10^{-15} s^2. Using steps (a) – (f) above, we obtain

$$\log_2(\text{PTPVAR}) = \frac{\ln(1.144 \times 10^{-15})}{\ln 2} = -49.6348$$

$$2^8 \log_2(\text{PTPVAR}) = \frac{(256)\ln(1.144 \times 10^{-15})}{\ln 2} = -12706.5176 \cong -12707$$

(IX.3)

Representing the above as a signed integer in 2s complement form produces

$$12707 = 31A3_{16} \rhd CE5C_{16} \text{ (1s complement form)} \rhd CE5D_{16} \text{ (2s complement form)}$$

(IX.4)

Adding 8000_{16} to the above and ignoring any overflow produces

$$CE5D_{16} + 8000_{16} = 14E5D_{16} \rhd 4E5D_{16}.$$

(IX.5)

The resulting offsetScaledLogVariance is $4E5D_{16}$.

IX.3.2 Computation of offsetScaledLogVariance for a T-GM timed by an ePRTC

The logarithm to base 2 of PTPVAR expressed in units of s^2 is computed and the result is multiplied by 2^8 to produce a scaled value.

$$\log_2(\text{PTPVAR}) = \frac{\ln(1.271 \times 10^{-16})}{\ln 2} = -52.8049$$

$$2^8 \log_2(\text{PTPVAR}) = \frac{(256)\ln(1.271 \times 10^{-16})}{\ln 2} = -13518.0507 \cong -13518$$

(IX.6)

Representing the above as a signed integer in 2s complement form produces

$$13518 = 34CE_{16} \Rightarrow CB31_{16} \text{ (1s complement form)} \Rightarrow CB32_{16} \text{ (2s complement form)}.$$

(IX.7)

Adding 8000_{16} to the above and ignoring any overflow produces

$$CB32_{16} + 8000_{16} = 14B32_{16} \Rightarrow 4B32_{16}.$$

(IX.8)

The resulting offsetScaledLogVariance is $4B32_{16}$.

Appendix X

Description of a T-BC extended clockClass application

(This appendix does not form an integral part of this Recommendation.)

Table 2 of [ITU-T G.8275.1] defines a T-BC extended clockClass application. This appendix describes the purpose of this extended application, and its corresponding value amendments, including defaultDS data set member specifications of Annex A of [ITU-T G.8275.1] (corresponding to Table A.1) and T-BC Announce message contents of Appendix V of [ITU-T G.8275.1] (corresponding to Table V.3).

X.1 Purpose of T-BC extended clockClass application

PTP is the only synchronization source in an [IEEE 1588] network, therefore the clockClass values have been only applied to the PTP clock for indicating its inherent characteristics. The clockClass in Table 5 of the [IEEE 1588] specification, such as 6,7,52,187, only represents the T-GM. The clockClass may not reflect the change of synchronization states in the T-BCs deployed in the network.

Since it is possible that there are two separate synchronization sources (GNSS time and physical frequency) in a telecom network, an extension mechanism of the clockClass range to cover the case of both T-GM and T-BC changes is provided. The definition of the clockClass values is extended into two parts:

1) for a T-GM, the range of clockClass includes 6, 7, 140, 150 and 160. The clockClass values of 140/150/160 represent the time output of T-GM when it is in time holdover instead of tracking to GNSS. The time quality is consistent with the clock quality of the frequency category 1, 2, and 3 respectively;

2) for a T-BC, the clockClass includes 135 and 165. The value of 135 means that when a T-BC is in time holdover, the output time signal is within specification, clockClass 165 means that the output time signal is out of time holdover specification.

The case of two separated sources has been considered in [ITU-T G.8271.1] HRM-2 and HRM-3. In order to extend the advantages of two separated sources, it is better to treat a T-BC differently when it is traceable to frequency of a different quality. The clockClass of 165 could be assigned to a T-BC when the T-BC is traceable to a frequency in QL=EEC/SEC, and the T-BC could share the clockClass value of 140/150/160 with the T-GM when it is traceable to a different quality of frequency. In this way, the appropriate T-BC can be selected to be the GM of the network so that better time signals can be sent to the end-users.

For a telecom network, it is crucial to make sure that the best clock selection principle is valid in any PTP network, especially in the case where there exists an isolated time region (which cannot receive any signals from the T-GM) in the network. In this region, if the T-BC has a preferred frequency quality, the T-BC can act as a T-GM, and send out precise time/phase signals (where the signal quality is still close to UTC). In telecom networks, from the perspective of synchronization performance, any of the T-BCs could supersede the old T-GM to be the new PTP source of the network.

X.2 DefaultDS data set member specifications under this extended application

In some cases, the values of clockClass/accuracy/variance will likely be the same as that delivered by the announce packets from the T-GM and T-BC per Table 2/Note 3. As such, the T-BC should synchronize the T-GM. It is suitable for priority 2 to achieve this goal, and the range of priority 2 should be divided into two parts, 0-127 for the T-GM, 128-255 for the T-BC.

In this PTP profile, the clock attribute priority2 is configurable.

If this feature is used, then the *priority2* for the T-GM should be set to a lower value compared to T-BCs, in particular the range for *priority2* could be allocated as follows:

–   for T-GM, the range {0-127};

–   for T-BC, the range {128-255}.

As an example of a default value for *priority2*, it is suggested to set the T-GM to 100 and the T-BC to 128.

Appendix XI

Considerations on native access equipment

(This appendix does not form an integral part of this Recommendation.)

In some deployments, native access equipment such as xDSL, xPON, and microwave equipment may have implemented T-BC functionality. This appendix provides information on how such equipment may be modeled as a pair of T-BCs defined in this Recommendation. The following Figure XI.1 shows an example of equipment that is transferring the PTP timing between native PTP and native access media. Examples of such equipment may be an xPON OLT & ONU, an xDSL DSLAM & RT-DSLAM, or microwave equipment. Only one PTP port and one Special port are shown in the diagram, although the equipment may contain multiple ports. Within this simplified diagram there are two PTP ports on the T-BC; one is a normal PTP port and one is a Special PTP port. On both the PTP port and the Special PTP port, the Announce information and Signalling messages are handled according to normal T-BC operation. The difference is that on the PTP port, the timing messages (Sync, Delay_Req, Delay_Resp) are handled normally, while on the Special PTP port they are not present as they are replaced by native timing messages. If the timing flow hierarchy is known in advance (such as that of a PON OLT, which will only transfer timing downstream on its Special PTP ports) then the PTP ports, Special PTP ports, or the PTP clock may be configured with masterOnly or slaveOnly parameters (such as a PON OLT configured with Special PTP ports as masterOnly TRUE, or a PON ONU configured with slaveOnly TRUE).

G.8275.1-Y.1369.1(16)-Amd.1(17)_FXI.1
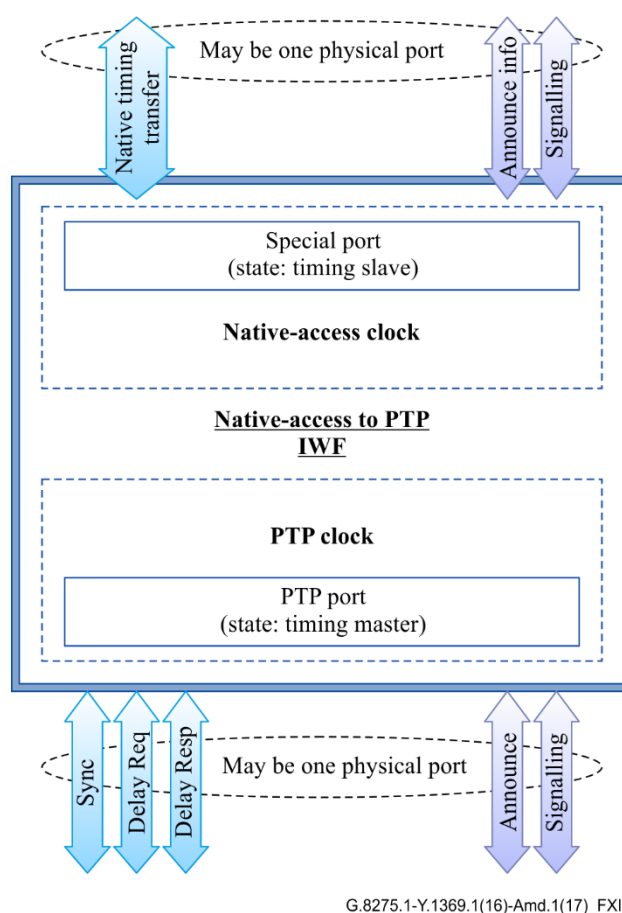
Figure XI.1 − Timing flow between native PTP and native access media

This appendix shows one possible way to model native access media (as a pair of T-BCs). Other ways to model native access media may exist.

Appendix XII

Monitoring alternate master time information provided by a peer PTP port

(This appendix does not form an integral part of this Recommendation.)

A PTP clock must synchronize only to a PTP port of its parent clock that is in the MASTER state. The synchronization must be received on, and only on, the port of the PTP clock that is in the SLAVE state. However, in some instances it may be desirable for a PTP port that is in the MASTER or PASSIVE state to receive time information from its peer in the MASTER, SLAVE, or PASSIVE state (see Figure IV.3 of [ITU-T G.8271] as an example application). It has been proposed that this monitoring be done using the alternateMasterFlag field defined in section 7.3.8.2 of [IEEE 1588] and a subset of the option of section 17.4 of [IEEE 1588]. This functionality, while not listed in section 9.2.4 of [IEEE 1588], is permitted when invoking section 17.4 of [IEEE 1588]. The use of this proposal for monitoring is suitable only for a limited set of use cases, specifically, small ring and small linear chain topologies (i.e., cases that contain a small number of PTP nodes). The use of the alternateMasterFlag for these use cases is for further study.

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