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

Recommendation ITU-T G.8275.2/Y.1369.2

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Recommendation ITU-T G.8275.2/Y.1369.2

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

Summary

Recommendation ITU-T G.8275.2/Y.1369.2 contains the ITU-T precision time protocol (PTP) profile for phase/time distribution with partial timing support from the network (unicast mode). 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. This Recommendation defines the PTP profile for unicast mode only. Future editions of this Recommendation may contain a separate profile for a mixed unicast/multicast case.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.8275.2/Y.1369.2	2016-06-22	15	11.1002/1000/12833

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

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* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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.

NOTE

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

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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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 partial timing support from the network

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 (and frequency) synchronization. The profile is based on the partial timing support (PTS) from the network architecture as described in [ITU-T G.8275] and definitions described in [ITU-T G.8260].

It is assumed that this profile will be used in well-planned cases where network behaviour and performance can be constrained within well-defined limits, including limits on static asymmetry. Control of static asymmetries can be achieved in case of assisted partial timing support. Use of this profile in non-assisted mode would require careful considerations on how to control static asymmetries.

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.

Further information on the setup of the protocol in the network is planned to be included in future versions of this Recommendation. In particular, this information will be related to architectures that imply rearrangements of the synchronization direction, and to architectures that include clocks with multiple PTP ports, especially when ports not in the MASTER state provide synchronization services.

At the time of publication of this profile, performance analysis, network limits, and clocks used in the profile, namely boundary and slave clocks, are for further study.

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

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.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), *Time and phase distribution through packet networks*.

[ITU-T G.8275.1] Recommendation ITU-T G.8275.1/Y.1369.1 (2016), *Precision time protocol telecom profile for phase/time synchronization with full timing support from the network.*

[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

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APTS Assisted Partial Timing Support

BC Boundary Clock

BMCA Best Master Clock Algorithm

ePRTC Enhanced Primary Reference Time Clock

EUI Extended Unique Identifier

GM GrandMaster

GNSS Global Navigation Satellite System

IP Internet Protocol

OC Ordinary Clock

ParentDS Parent Data Set

PDV Packet Delay Variation

PRC Primary Reference Clock

PRS Primary Reference Source

PRTC Primary Reference Time Clock

PTP Precision Time Protocol

PTPVAR PTP Variance

PTS	Partial Timing Support
PTSF	Packet Timing Signal Fail
QL	Quality Level
SDH	Synchronous Digital Hierarchy
SF	Signal Fail
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-P	Partial-Support Telecom Boundary Clock
TC	Transparent Clock
T-GM	Telecom Grandmaster
TLV	Type, Length, Value
T-TC-P	Partial-Support Telecom Transparent Clock
T-TSC-A	Assisted Partial-Support Telecom Time Slave Clock
T-TSC-P	Partial-Support Telecom Time Slave Clock
UDP	User Datagram Protocol
VLAN	Virtual Local Area Network

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 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 partial-support telecom boundary clock (T-BC-P) refers to a device consisting of a boundary clock (BC) as defined in [IEEE 1588], with additional performance characteristics for further study. A T-BC-P may be assisted by having a primary reference time clock (PRTC) (e.g., global navigation satellite system (GNSS)) support.

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

The term partial-support telecom time slave clock (T-TSC-P) refers to a device consisting of either an ordinary clock (OC), with one PTP port, or a boundary clock (BC), with multiple PTP ports, as defined in [IEEE 1588] and this Recommendation, that does not support providing synchronization using PTP to other PTP clocks in the PTP domain, and with additional performance characteristics for further study. A T-TSC-P may be assisted by having PRTC (e.g., GNSS) support.

The term assisted partial-support telecom time slave clock (T-TSC-A) refers to a T-TSC-P that is assisted by having PRTC (e.g., GNSS) support as a primary source of time. Note: In the case of a T-TSC-A or T-TSC-P, with multiple PTP ports (BC), only one PTP port can be in PTP SLAVE state at any instant in time based on the BMCA. Other PTP ports not in the PTP SLAVE state may actively exchange synchronization messages with other PTP clocks populated in the unicast master table using unicast negotiation.

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 standard was developed by the IEEE initially to support the timing requirements of industrial automation and test and measurement, defining 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 was defined by ITU-T in [ITU-T G.8265.1] to address applications requiring frequency synchronization only. An additional PTP profile was defined by ITU-T in [ITU-T G.8275.1] in order to allow the distribution of phase/time with full timing support from the network. This Recommendation defines another PTP profile to allow the distribution of phase and time with partial timing support (PTS) from the network.

The [IEEE 1588] telecom profile defined within this Recommendation is intended to be used by telecom applications requiring accurate phase and time synchronization. It covers applications where there is need for phase alignment and/or time of day. It supports the specific architecture described in [ITU-T G.8275] in order to allow the distribution of phase/time with PTS from the network, and is based on the 2008 version of PTP defined in [IEEE 1588]. This includes the case of assisted partial timing support (APTS).

This profile uses only the unicast mode.

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 [IEEE 1588] parameters 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. Those performance aspects are currently under study, and imply additional elements beyond the content of the PTP profile itself. These are planned to be addressed in other ITU-T Recommendations.

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. With that in mind, 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 partial-support telecom time slave clocks (T-TSC-P and T-TSC-A) to have the ability to take phase and time from multiple geographically separate T-GM 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 domain. 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 44, and the range of applicable PTP domain numbers is {44 – 63}.

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

[IEEE 1588] defines two categories of message types: event and general PTP messages. The two types differ in that event messages are timed messages and require or contain an accurate timestamp. General message types do not require accurate timestamps.

[IEEE 1588] defines the following message types: *Sync*, *Delay_Req* (i.e., "delay request"), *Announce*, *Follow_Up*, *Delay_Resp* (i.e., "delay response"), *Pdelay_Req*, *Pdelay_Resp*, and *Pdelay_Resp_Follow_Up*, *Management* and *Signalling.*

Sync, Delay_Req, Announce, Follow_Up, Delay_Resp, and Signalling messages are used in this profile.

Pdelay_Req, *Pdelay_Resp*, and *Pdelay_Resp_Follow_Up* messages are not used in this profile.

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

6.2.3 Types of PTP clocks supported in the profile

The OC and BC according to [IEEE 1588] are used in this profile.

There are two types of OCs:

1) 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) OC that can only be a slave, i.e., slave-only OC (T-TSC-P with only one port or T-TSC-A with only one port according to the architecture defined in [ITU-T G.8275]). The clock specifications for T-TSC-P and T-TSC-A are for further study.

There are three types of BCs:

1) 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) BC that can become a grandmaster and can also be slaved to another PTP clock (T-BC-P according to architecture defined in [ITU-T G.8275]). The clock specifications for T-BC-P are for further study.

3) BC that can only be a slave (T-TSC-P with more than one port or T-TSC-A with more than one port according to the architecture defined in [ITU-T G.8275]). The clock specifications for T-TSC-P and T-TSC-A are for further study.

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

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.8275.2] and PTP clock types

Clock type from [ITU-T G.8275.2]	Description	Clock type from [IEEE 1588]
T-GM	Master-only ordinary clock (master with a single PTP port, cannot be slaved to another PTP clock)	OC
	Master-only boundary clock (master with multiple PTP ports, cannot be slaved to another PTP clock)	BC (Note)
T-BC-P	Boundary clock (may become a GM, or may be slaved to another PTP clock)	BC
T-TSC-P	Slave-only, single port, ordinary clock (always a slave)	OC
	PTP clock at the end of the PTP synchronization chain, multiple port clock	BC (Note)
T-TSC-A	Slave-only, single port, ordinary clock (always a slave) with local PRTC assistance	OC
	PTP clock at the end of the PTP synchronization chain, multiple port clock with local PRTC assistance	BC (Note)
NOTE – According to [IEEE 1588], a clock that has multiple PTP ports is by definition a boundary clock.		

6.3 PTP modes

[IEEE 1588] describes several modes of operation between a master-port (which is a PTP in MASTER state) and a slave-port (which is a PTP port in SLAVE state). The term grant-port refers to a PTP port granting and providing PTP message service, and the term request-port refers to a PTP port requesting and receiving PTP message service. Typically, the grant-port is a master-port and the request-port is a slave-port. Information related to grant-ports and request-ports in other PTP states will be included in a future version of this Recommendation related to PTP clocks with multiple PTP ports.

NOTE 1 – A grant-port may be in the MASTER state, PASSIVE state, LISTENING state, PRE_MASTER state, UNCALIBRATED state, or SLAVE state. (but not INITIALIZING, FAULTY, or DISABLED state).

NOTE 2 – A request-port may be in the MASTER state, PASSIVE state, LISTENING state, PRE_MASTER state, UNCALIBRATED state, or SLAVE state. (but not INITIALIZING, FAULTY, or DISABLED state).

This clause describes these modes with respect to functionality needed to be compliant with this profile.

6.3.1 One-way versus two-way operation

A PTP master-port or grant-port compliant with the profile must be capable of supporting one-way and two-way timing transfers. For APTS, since only PTP synchronization may be required, a slave-port or request-port may only utilize one-way mode, or may utilize two-way mode, but is not required to support both methods; otherwise for PTS, a slave-port or request-port must utilize two-way.

NOTE – In the APTS case, even if performance objectives are specified by means of two-way metrics, this does not prevent the slave-port or request-port from utilizing one-way mode, although for a more accurate interpretation of how the network characteristics relates to the expected performance of the clock, two-way operation may be preferred.

6.3.2 One-step versus two-step clock mode

PTP defines two types of clock behaviour: the "one-step clock" and the "two-step clock". In a one-step clock, the precise timestamp is transported directly in the *Sync* message. In a two-step clock, a *Follow_Up* message is used to carry the precise timestamp of the corresponding *Sync* message. The use of *Follow_Up* messages is optional in the PTP protocol.

The one-step clock approach enables equipment to reduce significantly the number of PTP messages sent by the master-port or grant-port, and relax the master-port or grant-port capacities.

However, there might be situations where the two-step clock approach might be required (e.g., when some security features are required). These situations are for further study.

Both one-step and two-step clocks are allowed in the profile. A PTP master-port or grant-port compliant with the profile may use either a one-step clock or a two-step clock or both.

NOTE – The performance of the PTP timing flow generated by the master-port or grant-port with those two approaches is for further study.

To be compliant with [IEEE 1588], a slave-port or request-port must be capable of handling both one-step clock and two-step clock, without any particular configuration.

As per clause 7.3.8.3 of [IEEE 1588], when a two-step clock is used, the value of the flag "twoStepFlag" shall be TRUE to indicate that a *Follow_up* message will follow the *Sync* message, and that the slave-port or request-port must not consider the originTimestamp embedded in the *Sync* message. When a one-step clock is used, the value of the flag "twoStepFlag" shall be FALSE, and the slave-port or request-port must consider the originTimestamp embedded in the *Sync* message in this case.

6.3.3 Unicast versus multicast mode

PTP allows the use of unicast and multicast modes for the transmission of the PTP messages.

For the PTP profile specified in Annex A, the unicast mode is used for all the PTP messages.

A master-port or grant-port compliant with the PTP profile specified in Annex A must support the unicast mode.

A slave-port or request-port compliant with the PTP profile specified in Annex A must support the unicast mode.

6.4 PTP mapping

This PTP telecom profile is based on the PTP mapping defined in [IEEE 1588] Annex D, *Transport of PTP over User Datagram Protocol over Internet Protocol Version 4* and [IEEE 1588] Annex E, *Transport of PTP over User Datagram Protocol over Internet Protocol Version 6*.

Therefore, a master-port, grant-port, slave-port, or a request-port compliant with the profile described in this Recommendation must be compliant with [IEEE 1588] Annex D and may be compliant with [IEEE 1588] Annex E.

NOTE – The use of the Internet Protocol (IP)/user datagram protocol (UDP) mapping is to facilitate the use of IP addressing. It does not imply that the PTP flow can be carried over an unmanaged packet network. It is assumed that a well-controlled packet network will be used to control and minimize packet delay variation.

6.5 Message rates

The message rate values are only defined for protocol interoperability purposes. It is not expected that any slave clock shall meet the relevant target performance requirements at all packet rates within the given range, specifically at the lower packet rate. The appropriate value depends on the clock characteristics and on the target performance requirements. Different packet rate needs may also apply during the stabilization period.

NOTE – A specific slave clock implementation, in order to meet its target performance requirements, may support a subset of the message rates within the ranges noted below. A master-port or grant-port, on the other hand, is required to support the full range of message transmission rates. Unless an implementation specifies otherwise, the default value listed below is assumed to be used.

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

– *Sync* messages (if used, *Follow_up* messages will have the same rate) – minimum rate: 1 packet-per-second, maximum rate: 128 packets-per-second.

– *Delay_Req*/*Delay_Resp* messages – minimum rate:1 packet-per-second, maximum rate: 128 packets-per-second.

– *Announce* messages – minimum rate:1 packet-per-second, maximum rate: eight packets-per-second.

– *Signalling* messages – no rate is specified.

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

6.6 Unicast message negotiation

Within a telecommunication network, there are benefits to allowing PTP request-ports to request the synchronization service from PTP grant-ports. [IEEE 1588] offers a mechanism to allow request-ports to request this service within a unicast environment (see [IEEE 1588] clause 16.1). This profile supports the unicast message negotiation in accordance with [IEEE 1588] and as described below.

PTP clocks compliant with the profile must support the unicast negotiation mechanism as per clause 16.1 of [IEEE 1588] and as described in this clause.

When using the unicast mode, PTP request-ports request synchronization service by sending a PTP *Signalling* message in unicast, containing the REQUEST_UNICAST_TRANSMISSION type, length, value (TLV), to the IP address of the selected PTP grant-port.

NOTE 1 – In this telecom profile, unicast connection establishment without negotiation is for further study.

The *Signalling* message containing the REQUEST_UNICAST_TRANSMISSION TLV is periodically renewed.

When initiating unicast negotiation with a grant-port, a request-port can use all 1's as the initial value for the targetPortIdentity field of the Signalling message. Based on the response from the grant-port, the request-port can then learn the clockIdentity and portNumber of the grant-port and may use this in any subsequent Signalling message. The request-port may also continue to use all 1's. Similarly, the grant-port may either learn and use the clockIdentity and portNumber of the request-port, or use all 1's value for the targetPortIdentity field of the Signalling messages that it sends. Both grant-port and request-port must be prepared to handle both situations in reception, i.e., receive PTP Signalling messages with either their own clockIdentity and portNumber or with all 1's values for the targetPortIdentity field.

The logInterMessagePeriod can be configured to adjust the requested transmission rate of *Sync*, *Announce* and *Delay_Resp* messages.

The configurable range for the logInterMessagePeriod is given in Annex A for all the relevant messages.

The durationField value in each REQUEST_UNICAST_TRANSMISSION TLV has a default initialization value of 300 seconds and a configurable range of 60 to 1000 seconds.

In the event that a PTP grant-port is unable to meet a given request-port request, it should deny the request entirely rather than offer the request-port less than it originally requested.

In the event of being denied service by a grant-port, or receiving no response to the service request:

– A request-port should wait a minimum of one second (after denial or no response received) before issuing a new unicast service request for that message type to the same grant-port.
– If a request-port has issued three service requests for the same message type with either no response or a "grant denied" response, it should either:
  - cancel any granted unicast service it may have for other message types, and request service from a different grant-port, or
  - wait a further 60 seconds before re-issuing the request to the same grant-port.

An example of the message exchange to initiate the unicast synchronization service is shown in Figure 1. The timing diagram example represents the exchange of unicast messages for a one-step clock (i.e., no *Follow_up* messages) using one-way mode (i.e., no *Delay_Req* or *Delay_Resp*).

The example shows a unicast negotiation process for a packet request-port sending *Signalling* messages for *Announce* and *Sync* requests; a packet grant-port granting the packet request-port the requested message rates; a packet grant-port transmitting the requested *Announce* and *Sync* message rates and the renewal of *Announce* and *Sync* before the expiration of durationField.

Note that several timing diagrams could be represented based on various exchanges of message types, the use of single or concatenated TLVs in *Signalling* messages, the use of different durationFields for each message type, etc. Figure 1 provides an example of message interaction; it is for illustrative purposes only and does not represent a particular implementation.

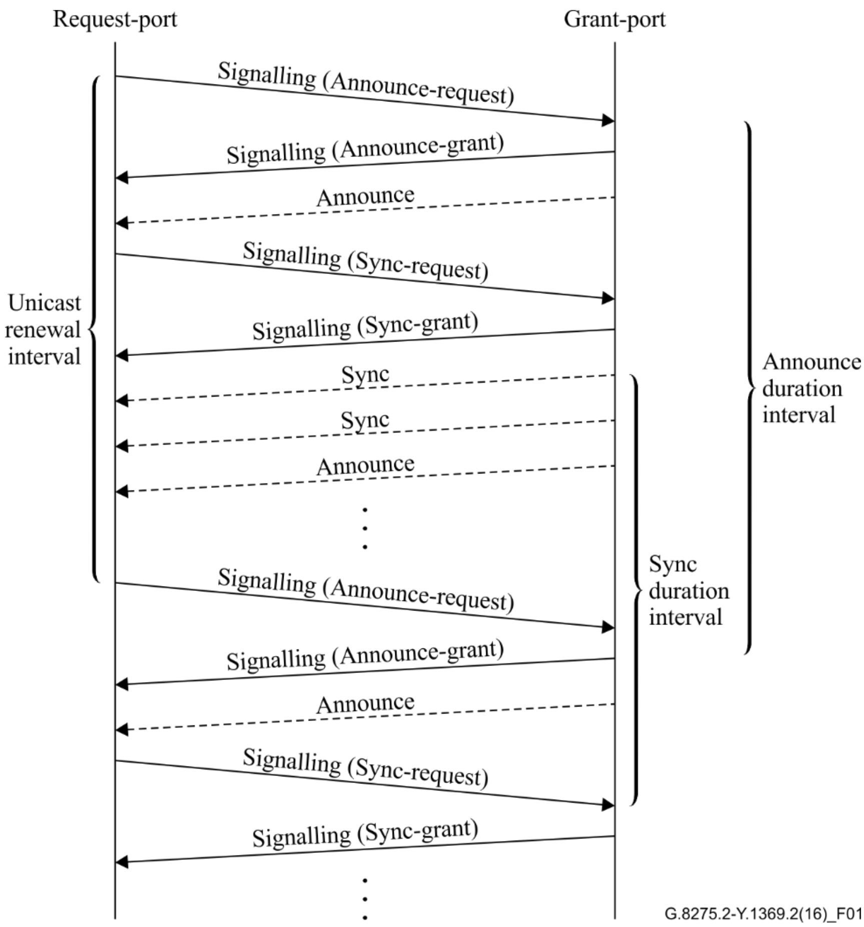

Figure 1 – Unicast negotiation example

PTP request-ports may request several types of PTP messages from a PTP grant-port (e.g., request-port working in two-way mode, which may request *Sync* and *Delay_Resp* messages, or request-port requesting *Announce* and *Sync* messages from the same grant-port). To request unicast transmission of different PTP message types, and to respond to such requests, [IEEE 1588] allows the use of a single *Signalling* message containing multiple TLVs or the use of multiple *Signalling* messages. Grant-ports and request-ports compliant with this profile must be prepared to handle those two situations. The expected behaviour during the initial negotiation and during the consecutive unicast service renewals is described in the paragraphs that follow.

Each request for unicast transmission from a specific request-port to a grant-port should start by issuing an *Announce* service type request first for that specific grant-port. Only after the request-port has been granted unicast service for the *Announce* message and received the first unicast *Announce* message from the specified grant-port, can the rest of the service type request take place. Such practice would ensure that the attributes (e.g., clockQuality) and capabilities of the specified grant-port are acceptable from the request-port's perspective before the rest of the services are contracted.

Upon receiving the first *Announce* message from the grant-port, the first *Signalling* message containing a REQUEST_UNICAST_TRANSMISSION TLV issued by the request-port should include all the service types the specific request-port requires from the grant-port using multiple REQUEST_UNICAST_TRANSMISSION TLVs. Such practice will reduce the chance that the grant-port will only grant part of the requested services in case it has been over-subscribed (due to simultaneous requests from other request-ports). The grant-port is allowed to respond to this request either with a single *Signalling* message containing multiple TLVs, or with multiple *Signalling* messages (e.g., each containing a single TLV).

When renewing the unicast services, the request-port, in sending *Signalling* messages (for 'keep-alive' purposes), may either continue to request all service types with a single *Signalling* message containing multiple TLVs, or with multiple independent *Signalling* messages (e.g., each containing a single TLV). The grant-port is allowed to respond to requests either with a single *Signalling* message containing multiple TLVs, or with multiple *Signalling* messages (e.g., each containing a single TLV).

The following text provided in clause A.9.4.2 of [IEEE 1588] should be followed: "For receiving continuous service, a requester should reissue a request in advance of the end of the grant period. The recommended advance should include sufficient margin for reissuing the request at least two more times if no grant is received."

In case the unicast transmission sessions are cancelled as defined in clause 16.1.1 of [IEEE 1588], a PTP clock cancelling several types of PTP messages may use a single *Signalling* message containing multiple TLVs or multiple *Signalling* messages. Grant-ports and request-ports compliant with this profile must be prepared to handle those two situations.

The PTP clock cancelling the session may either cancel the multiple service types with a single *Signalling* message containing multiple CANCEL_UNICAST_TRANSMISSION TLVs, or with multiple independent *Signalling* messages (e.g., each containing a single CANCEL_UNICAST_TRANSMISSION TLV). The other PTP clock receiving the cancellation is allowed to respond to these requests either with a single *Signalling* message containing multiple ACKNOWLEDGE_CANCEL_UNICAST_TRANSMISSION TLVs, or with multiple independent *Signalling* messages (e.g., each containing a single ACKNOWLEDGE_CANCEL_UNICAST_TRANSMISSION TLV).

NOTE 2 – The "renewal invited" flag described in [IEEE 1588] clause 16.1.4.2.6 is not used in this profile.

6.7 Alternate BMCA, telecom slave model and master selection process

This clause describes the Alternate BMCA algorithm, the telecom slave model and the associated master selection process. These are described in the following clauses.

6.7.1 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] in the following:

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-P or T-TSC-A) 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-P) are TRUE and {TRUE, FALSE}.

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 3 and Figure 4 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 3 and 4 in clause 6.7.9.

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 (see Figure 2 below), depending on the status of the T-GM (i.e., clockClass value of the T-GM).

NOTE 3 – When the value of the masterOnly attribute is TRUE on a PTP port, the PTP port typically does not request unicast services from other ports.

6.7.2 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.

6.7.3 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.

6.7.4 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-P clocks to the midpoint value, 128, of its range {0-255}. The default value for T-TSC-P and T-TSC-A clocks is 255, and the range is {255}.

A T-GM or T-BC-P compliant with this PTP profile must support all the values of priority2 defined in the range. A T-TSC-P or T-TSC-A 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 I describes possible use cases for the priority2 attribute; other cases are for further study.

6.7.5 Clock attribute clockClass

A PTP clock compliant with this PTP profile must support all values of clockClass upon reception (shall not discard) defined in the full [IEEE 1588] range. The applicable values of the clock attribute clockClass are specified in clause 6.8 of this Recommendation.

NOTE 1 – The behaviour on reception of a clockClass value not specified in Table 2 is for further study.

6.7.6 Clock attribute clockAccuracy

A PTP clock compliant with this PTP profile must support all the values of clockAccuracy upon reception (shall not discard) defined in the full [IEEE 1588] range. The values that can be transmitted in the clockAccuracy field are shown in Table A.1. The following values of the clock attribute clockAccuracy apply for the following situations:

– 0x20 for a T-GM connected to an ePRTC in locked-mode (i.e., e PRTC traceable to GNSS).
– 0x21 for a T-GM connected to a PRTC in locked-mode (i.e., PRTC traceable to GNSS).
– 0xFE for a T-BC-P not connected to a GNSS in locked mode on a virtual PTP port.

The clockAccuracy for a T-BC-P when connected to a GNSS in locked mode on a virtual PTP port is for further study.

6.7.7 Clock attribute offsetScaledLogVariance

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 seconds. The corresponding value of PTP Variance (PTPVAR) is 1.271×10^{-16} s^2 (see Appendix IX of [ITU-T G.8275.1]).
– 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 seconds. The corresponding value of PTPVAR is 1.144×10^{-15} s^2 (see Appendix IX of [ITU-T G.8275.1]).
– 0xFFFF for a T-GM not connected to a PRTC in locked-mode.
– 0xFFFF for a T-BC-P not connected to a GNSS in locked mode on a virtual PTP port.

The offsetScaledLogVariance for a T-BC-P when connected to a GNSS in locked mode on a virtual PTP port is for further study.

6.7.8 State decision algorithm

The state decision algorithm applicable to the Alternate BMCA of the PTP profile specified in this Recommendation is given in Figure 2. 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].

6.7.9 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 3 and 4 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 3 and 4 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 6.7.1).

If either of the data sets, A or B, in Figures 3 and 4 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 6.7.1).

NOTE 1 – It is recommended that the entire data set comparison algorithm described in Figures 3 and 4 be implemented even if some parameters are currently static, because they may be used in future versions of this Recommendation.

NOTE 2 – For the block "Compare SF values of A and B" in Figure 3, the comparison is made based on the values of 1 for TRUE and 0 for FALSE. Signal fail (SF) is described in clause 6.7.11.

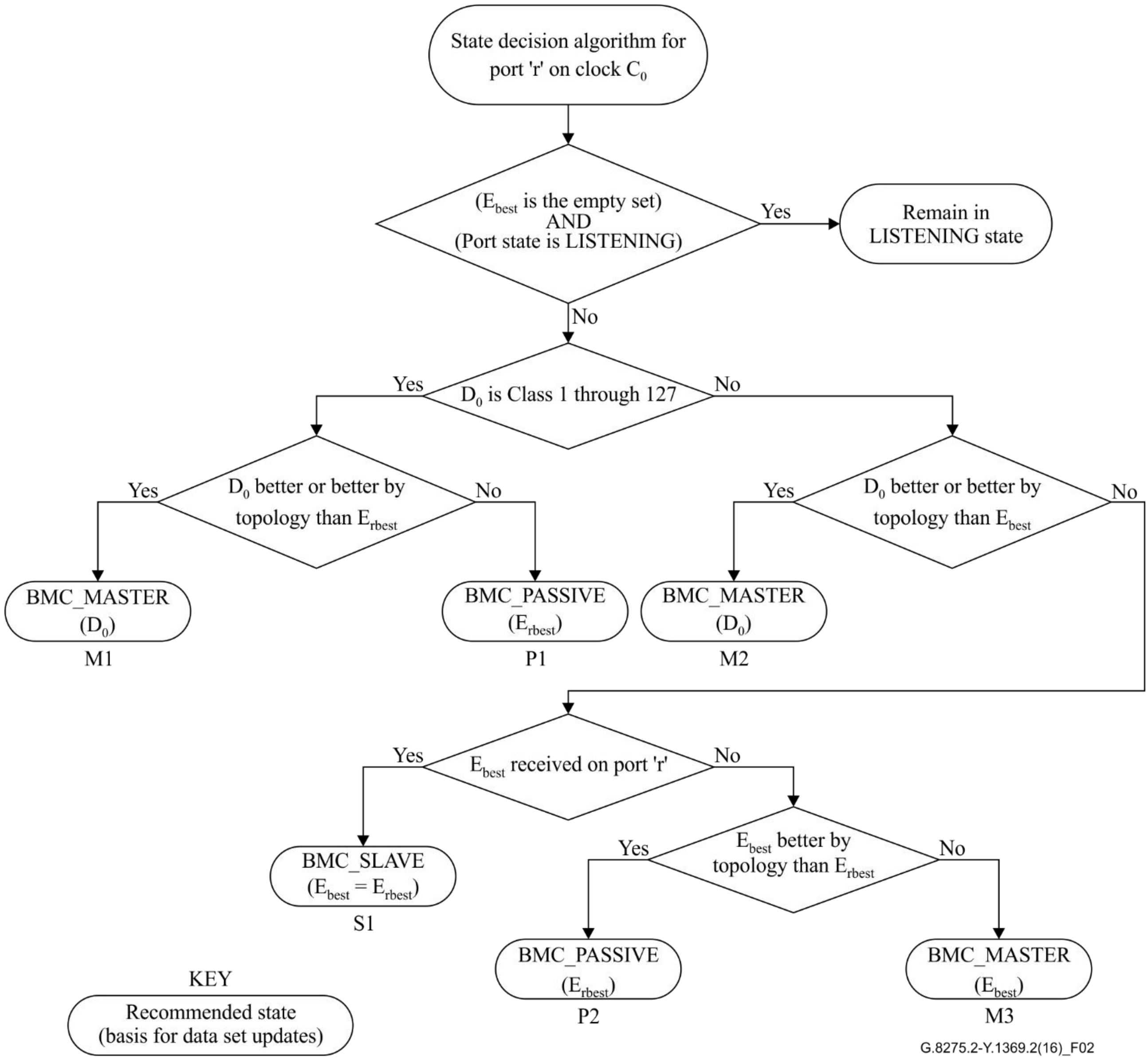

Figure 2 – State decision algorithm for Alternate BMCA

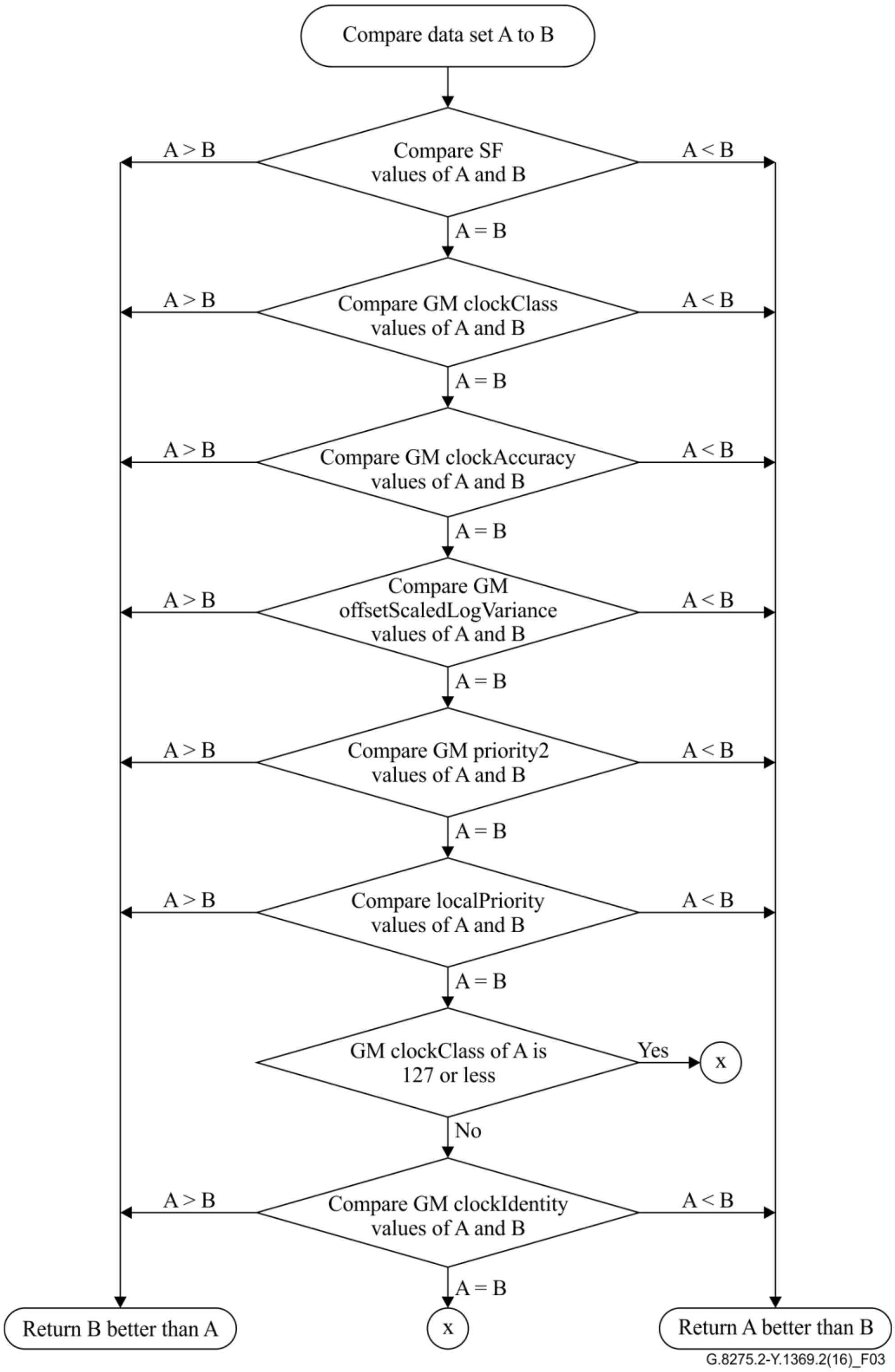

Figure 3 – Data set comparison algorithm, part 1, for Alternate BMCA

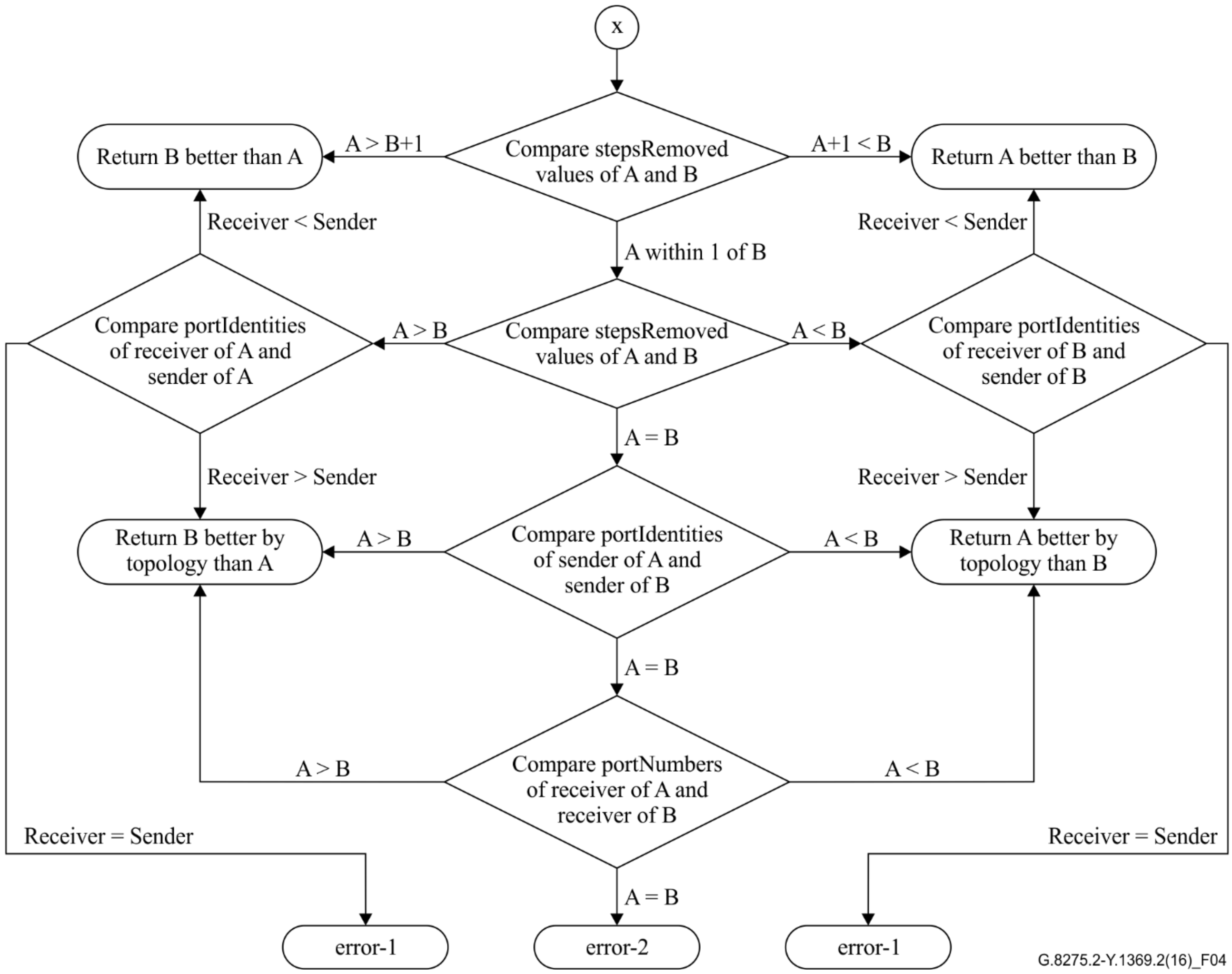

Figure 4 – Data set comparison algorithm, part 2, for Alternate BMCA

NOTE 3 – stepsRemoved used in the BMCA does not characterize or reflect the amount of packet delay variation (PDV) or asymmetry on a connection. The BMCA may not select the path with the lowest PDV or asymmetry.

6.7.10 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.6 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 6.7.3.

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 – 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 6.7.4, 6.7.5, 6.7.6 and 6.7.7), the ranges for reception and 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. The clock's local data set must not be updated with the ingress value.

– domainNumber
– versionPTP
– flagField – unicastFlag

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 [IEEE 1588] ranges, see clauses 6.7.4, 6.7.5, 6.7.6 and 6.7.7 of this Recommendation.

6.7.11 Packet timing signal fail

This clause defines the notion of packet timing signal fail (PTSF), which corresponds to a signal indicating a failure of the PTP packet timing signal received by the slave.

Two types of PTSF may be raised in a slave implementation:

1) PTSF-lossSync, lack of reception of PTP timing messages from a master (loss of the packet timing signal): if the slave no longer receives the timing messages sent by a master (i.e., *Sync* and subsequently *Follow_up* and *Delay_Resp* messages), then a PTSF-lossSync associated to this master must occur. A timeout period for reception of Sync messages or Delay_Resp messages (these are analogous to "syncReceiptTimeout" and "delayRespReceiptTimeout" in [ITU-T G.8265.1]) for these timing messages must be implemented in the slave before triggering the PTSF-lossSync (the range and default value of this timeout parameter are for further study).

2) PTSF-unusable, unusable PTP packet timing signal received by the slave, exceeding the input tolerance of the slave (noisy packet timing signal): if the PTP packet timing signal is not usable for the slave to achieve the performance target (e.g., violates the slave input tolerance because of excessive PDV noise), then a PTSF-unusable associated to this master must occur. The criteria used to determine that the packet timing signal is not suitable to be used is for further study (An example of criteria to be studied may relate to the PDV experienced by the packet timing signal as it traverses the network from the master to the slave).

When a PTSF occurs, the clock will set the PTP portDS.SF to TRUE and generate a state decision event.

6.8 Phase/time traceability information

In order to deliver phase/time traceability information, the clockClass values described in Table 2 below must be used in this PTP telecom profile.

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 6.7; the values provided for this flag in Table 2 can be used by the network operator for monitoring purposes or by the end applications to take definitive action as described in Appendix II.

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 physical layer frequency signal received on an external interface).

As an example, when a T-BC-P 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-P 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.

NOTE 2 – The case of a T-BC-P 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-P with a phase/time external synchronization input different from PRTC is for further study.

Table 2 – Applicable clockClass values

Phase/time traceability description	defaultDS 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-P in holdover, within holdover specification, traceable to Category 1 frequency source (Note 1)	135	TRUE	TRUE
T-BC-P in holdover, within holdover specification, non-traceable to Category 1 frequency source (Note 1)	135	FALSE	TRUE
T-GM in holdover, out of holdover	140	TRUE	FALSE

Table 2 – Applicable clockClass values

Phase/time traceability description	defaultDS clockClass	frequencyTraceable flag	timeTraceable flag
specification, traceable to Category 1 frequency source (Note 1)			
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-P in holdover, out of holdover specification (Note 1)	165	(Note 2)	FALSE
T-GM, T-BC-P, T-TSC-P, or T-TSC-A without time reference since start-up	248	(Note 2)	FALSE
T-TSC-P or T-TSC-A acting as an OC	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-P 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. For a description of frequency source "Category" see Table 3 below.

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 – 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

6.9 Use of alternate master flag

A PTP clock must only synchronize to a PTP timing service being provided by its parent clock, whose port is in the PTP MASTER state. To ensure this operation, this profile uses the alternateMasterFlag field defined in clause 7.3.8.2 of [IEEE 1588] with the following behaviour.

a) On transmission of an Announce message, a PTP port will set the alternateMasterFlag to 0 when the transmitting PTP port state is MASTER; otherwise the PTP port must set the alternateMasterFlag to 1.

b) Referring to clause 13.3.2.6 of [IEEE 1588], the alternateMasterFlag is only set on transmission of Announce, Sync, Follow_Up and Delay_Resp messages.

c) On reception, a PTP port that receives a PTP Announce message with alternateMasterFlag value 1 must discard (and not process) the message. For example, such an Announce message must not be input into the BMCA.

While the alternateMasterFlag is used in this version of the profile, clause 17.4 of [IEEE 1588] is not used.

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

The [IEEE 1588] profile that supports time distribution in unicast mode is contained in Annex A.

8 Security aspects

Security aspects are for further study.

Annex A

ITU-T PTP profile for time distribution with partial timing support from the network (unicast mode)

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

This annex contains the telecom profile for time distribution as required by [IEEE 1588]. In order to claim compliance with the 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 time distribution with partial timing support from the network (unicast mode)

profileVersion: 1.0

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

This profile is specified by ITU-T.

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

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 and A.5. 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 shall use the [IEEE 1588] default initialization values and ranges.

Table A.1 – defaultDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Partial support telecom time slave clock requirements		Partial support 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 for OC As per PTP for BC	{1} for OC As per PTP for BC	As per PTP	As per PTP
8.2.1.3.1.1	defaultDS.clockQuality. clockClass (dynamic)	248	{6, 7, 140, 150, 160, 248}	255 for OC 248 for BC	{255} for OC {248} for BC	248	{135, 165, 248}
8.2.1.3.1.2	defaultDS.clockQuality. clockAccuracy (dynamic)	0xFE (Note 2)	As per PTP (Note 2) (Note 4)	0xFE (Note 2)	{0xFE} (Note 2)	0xFE (Note 2)	{0xFE} (Note 2)
8.2.1.3.1.3	defaultDS.clockQuality. offsetScaledLogVariance (dynamic)	0xFFFF	As per PTP (Note 4)	0xFFFF	{0xFFFF}	0xFFFF	{0xFFFF}
8.2.1.4.1	defaultDS.priority1 (configurable)	128 (Note 1)	{128} (Note 1)	128 (Note 1)	{128} (Note 1)	128 (Note 1)	{128} (Note 1)
8.2.1.4.2	defaultDS.priority2 (configurable)	128	{0-255}	255	{255}	128	{0-255}
8.2.1.4.3	defaultDS.domainNumber (configurable)	44	{44-63}	44	{44-63}	44	{44-63}
8.2.1.4.4	defaultDS.slaveOnly (configurable)	FALSE	{FALSE}	TRUE for OC FALSE for BC	{TRUE} for OC {FALSE} for BC	FALSE	{FALSE}
New member	defaultDS.localPriority (configurable)	128	{1-255}	128	{1-255}	128	{1-255}
New member	defaultDS.SF (dynamic)	FALSE	{FALSE}	FALSE	{FALSE}	FALSE	{FALSE}

NOTE 1 – As per PTP, not applicable for this profile.

NOTE 2 – For the case where the PTP grandmaster is syntonized to a PRC for frequency, but not synchronized to a reference source of time, the grandmaster should set defaultDS.clockQuality.clockAccuracy to 0xFE, "UNKNOWN".

NOTE 3 –Equipment implementing multiple slave ports, with defaultDS.clockClass value of 255, should be treated as having multiple instantiations of slave-only OCs. This is out of scope of this Recommendation.

NOTE 4 –Examples of applicable values are shown in clauses 6.7.6 and 6.7.7.

Table A.2 – currentDS data set member specifications

Clause from [IEEE 1588]	Members of the data set	Telecom grandmaster requirements		Partial support telecom time slave clock requirements		Partial support 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		Partial support telecom time slave clock requirements		Partial support telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.3.2	parentDS.parentPortIdentity (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.observedParentOffsetScaledLogVariance (dynamic)	(Note)	(Note)	(Note)	(Note)	(Note)	(Note)
8.2.3.5	parentDS.observedParentClockPhaseChangeRate (dynamic)	(Note)	(Note)	(Note)	(Note)	(Note)	(Note)
8.2.3.6	parentDS.grandmasterIdentity (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.3.7	parentDS.grandmasterClockQuality (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.3.8	parentDS.grandmasterPriority1 (dynamic)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)
8.2.3.9	parentDS.grandmasterPriority2 (dynamic)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)	As per PTP (Note)
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		Partial support telecom time slave clock requirements		Partial support telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.4.2	timePropertiesDS.currentUtcOffset (dynamic)	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP	As per PTP
8.2.4.3	timePropertiesDS.currentUtcOffsetValid (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.4	timePropertiesDS.leap59 (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.5	timePropertiesDS.leap61 (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.6	timePropertiesDS.timeTraceable (dynamic)	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}	FALSE	{FALSE, TRUE}
8.2.4.7	timePropertiesDS.frequencyTraceable (dynamic)	FALSE	{FALSE, TRUE} (Note)	FALSE	{FALSE, TRUE} (Note)	FALSE	{FALSE, TRUE} (Note)
8.2.4.8	timePropertiesDS.ptpTimescale (dynamic)	TRUE	{TRUE}	TRUE	{TRUE}	TRUE	{TRUE}
8.2.4.9	timePropertiesDS.timeSource (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 partial support telecom time slave clock		Partial support telecom boundary clock requirements	
		Default initialization value	Range	Default initialization value	Range	Default initialization value	Range
8.2.5.2.1	portDS.portIdentity.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
8.2.5.2.1	portDS.portIdentity.portNumber (static)	1 for OC As per PTP for BC	{1} for OC As per PTP for BC	1 for OC As per PTP for BC	{1} for OC As per PTP for BC	As per PTP	As per PTP
8.2.5.3.1	portDS.portState	As per PTP	As per	As per PTP	As per	As per PTP	As per PTP

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 partial support telecom time slave clock		Partial support telecom boundary clock requirements	
	(dynamic)		PTP		PTP		
8.2.5.3.2	portDS.logMinDelayReqInterval (dynamic)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)
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)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)
8.2.5.4.2	portDS.announceReceiptTimeout (configurable)	2	{2}	As per PTP	As per PTP	As per PTP	As per PTP
8.2.5.4.3	portDS.logSyncInterval (configurable)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)	(Note 1)
8.2.5.4.4	portDS.delayMechanism (configurable)	01 (Note 2)	{01} (Note 2)	'01' for a two-way slave-port, and 'FE' for a one-way slave-port	{01,FE}	01	{01}
8.2.5.4.5	portDS.logMinPdelayReqInterval (configurable)	(Note 1)	(Note)	(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}
New member	portDS.SF (dynamic)	FALSE	{FALSE}	FALSE	{TRUE, FALSE}	FALSE	{TRUE, FALSE}

NOTE 1 – As per PTP, not applicable for this profile.
NOTE 2 – The master must support two-way operation.

A.3 PTP options

A.3.1 Node types required, permitted or prohibited

In this profile, the permitted node types are: ordinary clocks and boundary clocks.

The use of transparent clocks is for further study.

A.3.2 Transport mechanisms required, permitted, or prohibited

In this profile, the required transport mechanism is UDP/IPv4 as per Annex D in [IEEE 1588]. Bit 0 of the transportSpecific field must be set to "0".

In this profile, a permitted transport mechanism is UDP/IPv6 as per Annex E in [IEEE 1588].

A.3.3 Unicast messages

All messages are sent in unicast.

In this telecom profile, unicast negotiation is enabled per default.

The slave will initiate the session by following the unicast message negotiation procedure defined in [IEEE 1588] clause 16.1.

A.3.4 REQUEST_UNICAST_TRANSMISSION TLV

The value of logInterMessagePeriod is the logarithm, to base 2, of the requested mean period, in seconds, between the requested unicast messages.

For requesting unicast *Announce* messages: The configurable range is 0 to –3 (which represents a range from 1 message per second to eight messages per second). No default rate is specified.

For requesting unicast *Sync* messages: The configurable range is 0 to –7 (which represents a range from 1 message per second to 128 messages per second). No default rate is specified.

For requesting unicast *Delay_Resp* messages: The configurable range is 0 to –7 (which represents a range from 1 message per second to 128 messages per second). No default rate is specified.

The durationField value in each REQUEST_UNICAST_TRANSMISSION TLV has a default initialization value of 300 seconds. The configurable range is 60 seconds to 1000 seconds.

NOTE 1 – A specific slave implementation, in order to meet its target performance requirements, as normal operation, may support a subset of the message rates within the ranges noted above. A master, on the other hand, is required to support the full range of message transmission rates. Unless an implementation specifies otherwise, the default value listed above is assumed to be used.

NOTE 2 – A specific slave implementation may support a subset of the durationField values within the range noted above. A master, on the other hand, is required to support the full range of durationField values. Unless an implementation specifies otherwise, the default value listed above is assumed to be used.

The maintenance and configuration of these default and configuration range values is implementation specific.

A.3.5 GRANT_UNICAST_TRANSMISSION TLV

In implementing the GRANT_UNICAST_TRANSMISSION TLV mechanism, the granted values shall be the same as requested in the received REQUEST_UNICAST_TRANSMISSION TLV as long as the requests are in the configurable range.

A.4 Best master clock algorithm options

This profile uses the Alternate BMCA described in clause 6.7 of this Recommendation.

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

The delay request/delay response mechanism can be used in this profile. The peer delay mechanism shall not be used in this profile.

A.6 Configuration management options

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

A.7 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 extended unique identifier (EUI) formats are not supported.

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 alternate timescales (clause 16.3), grandmaster clusters (clause 17.3), alternate master (clause 17.4), acceptable master table (clause 17.6), and the experimental cumulative frequency scale factor offset (Annex L) all within [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.6.

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, the values shall be FALSE."

Table A.6 – PTP flags

Flag	Value to be sent	Behaviour for the receiving node
alternateMasterFlag	See clause 6.9 of this Recommendation	Used
twoStepFlag	As per PTP	Used
unicastFlag	TRUE	Used
PTP profile Specific1	FALSE	Flag is ignored
PTP profile Specific2	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.		

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:

1) Automatic topology establishment: 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.

2) Manual network planning: 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 on a PTP clock

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

This annex describes the model for inclusion of a unidirectional, external phase/time input interface in a T-GM, T-BC-P, or T-TSC-A, 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 PTP clock, in order to allow this external interface to participate in the PTP protocol.

The following attributes are associated to the virtual PTP port:

– SF
– clockClass
– clockAccuracy
– offsetScaledLogVariance
– localPriority
– priority1
– priority2
– timeProperties
  • currentUtcOffsetValid
  • leap61
  • leap59
  • timeTraceable
  • frequencyTraceable
  • ptpTimescale
  • timeSource
  • currentUtcOffset

The signal fail (SF), like localPriority, is a local property of the PTP clock. SF is set to TRUE when the PTP clock determines the virtual PTP port input (e.g., 1PPS, GNSS) is not useable. When SF is TRUE the portDS.SF parameter is set to TRUE. The priority1 attribute must be set to 128.

The priority2 attribute default is 128, with configurable range 0-255.

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 PTP clock itself. The portNumber assigned to the virtual PTP port is set to a value different from the portNumber values already assigned to the clock's 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 a PTP clock 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 defined in [ITU-T G.8271].

Annex D

TLV for PTP interface rate (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 port in MASTER state that is providing timing service has a different interface rate than a PTP port in SLAVE state receiving the timing service, delay asymmetry may occur as described in [ITU-T G.8271] Appendix V 'Delay asymmetry resulting from interface rate change in PTP-unaware network elements'. If the slave clock is aware of both its own PTP port interface rate, as well as the master clock PTP port interface rate, then the slave clock may compensate for such delay asymmetry. The following TLV may be appended to a signalling message that contains GRANT_UNICAST_TRANSMISSION TLV so that the master clock may communicate its PTP port interface rate to the slave clock.

Table D.1 – INTERFACE_RATE TLV

Bits								Octets	TLV offset
7	6	5	4	3	2	1	0		
tlvType								2	0
lengthField								2	2
organizationId								3	4
organizationSubType								3	7
interfaceBitPeriod								8	10
numberBitsBeforeTimestamp								2	18
numberBitsAfterTimestamp								2	20

tlvType (Enum16)

The value of tlvType shall be the ORGANIZATION_EXTENSION value (0x003)

lengthField (Uinteger16)

The value of lengthField shall be 18 bytes.

organizationId (Octet [3])

The value of organizationId shall be the OUI value assigned by ITU-T = 0x0019A7.

organizationSubType (Enum24)

The value of organizationSubType for the INTERFACE_RATE TLV shall be 0x000002.

interfaceBitPeriod (Uinteger64)

The period of 1-bit of the transmitting PTP timestamp interface, excluding line encoding. The value is encoded as an unsigned integer in units of attoseconds (10^{-18} s) to accommodate interface bit periods less than 1 ns.

numberBitsBeforeTimestamp (Uinteger16)

The length of the packet prior to the timestamp point, in bits.

numberBitsAfterTimestamp (Uinteger16)

The length of the packet after the timestamp point, in bits.

By way of example, the following values may be used for 1 GbE interface with Annex D encapsulation.

– tlvType = 0x003
– lengthField = 18
– organizationId = 0x0019A7.
– organizationSubType = 0x000002
– interfaceBitPeriod = 0x0000,0000, 3B9A, CA00
– numberBitsBeforeTimestamp = (8 bytes pre-amble x 8 bits/byte) = 64
– numberBitsAfterTimestamp = ((86 bytes payload + 4 bytes FCS) x 8 bits/byte) = 720

NOTE 1 – The supported interfaces (and interface speed) for an equipment clock are listed in the relevant equipment clock specification, such as ITU-T G.8273.4, and not in this profile.

NOTE 2 – The TLV and interfaceBitPeriod format is applicable to single-lane and mutli-lane interfaces.

Table D.2 shows information about various interface speeds and the appropriate interfaceBitPeriod value.

Table D.2 – Informational interface speeds and type mappings

Interface Speed	ns per bit	Atto-sec per bit	64-bit atto-sec Representation
1	1,000,000,000.000	10^{18}	0x0DE0,B6B3,A764,0000
10 M	100.000	100,000,000,000	0x0000,0017,4876,E800
100 M	10.000	10,000,000,000	0x0000,0002,540B,E400
1G	1.000	1,000,000,000	0x0000,0000,3B9A,CA00
10 G	0.100	100,000,000	0x0000,0000,05F5,E100
25G	0.040	40,000,000	0x0000,0000,0262,5A00
40G	0.025	25,000,000	0x0000,0000,017D,7840
100G	0.010	10,000,000	0x0000,0000,0098,9680
1 T	0.001	1,000,000	0x0000,0000,000F,4240

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.

Appendix I

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-BC-Ps either traceable to one T-GM, or traceable to two different T-GMs at the same time.

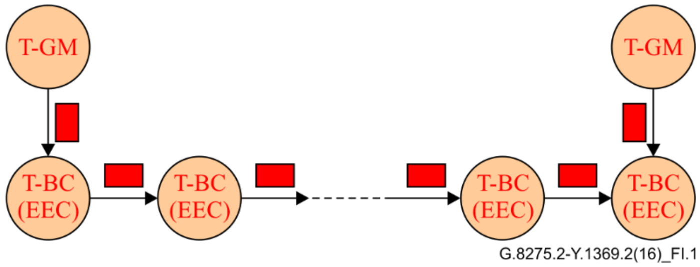

Figure I.1 – Use of priority2 with two T-GMs in the network

For example, in Figure I.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-P will select the T-GM with the shortest path. If the two T-GMs are configured with different priority2 values, all of the T-BC-Ps will synchronize to the T-GM with the smallest priority2 value.

Case 2

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

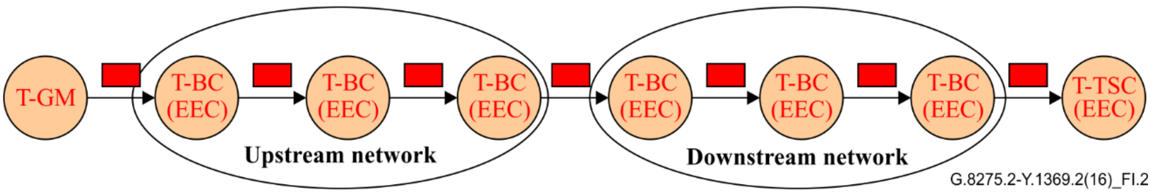

Figure I.2 – Use of priority2 with T-BCs of different network layers

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

Appendix II

Considerations on a T-TSC-A or T-TSC-P connected to an end application

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

The default T-TSC-A and T-TSC-P clockClass (248 for BC and 255 for OC) generally implies that the T-TSC-A or T-TSC-P will lock to the co-located PRTC (in case of APTS) or 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-A or T-TSC-P (e.g., instead of entering holdover), could depend on the actual clockQuality, frequencyTraceable flag and timeTraceable flag associated to the T-TSC-A or T-TSC-P input. 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], it would be necessary that the external 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 on the internal oscillator or driven by synchronous Ethernet).

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