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

Packet over Transport aspects – Synchronization, quality and availability targets

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet protocol aspects – Transport

Precision time protocol telecom profile for frequency synchronization

Recommendation ITU-T G.8265.1/Y.1365.1

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Precision time protocol telecom profile for frequency synchronization

Summary

Recommendation ITU-T G.8265/Y.1365 describes the architecture and requirements for packet-based frequency distribution in telecom networks. Examples of packet-based frequency distribution include the network time protocol (NTP), IEEE-1588-2008 and IEEE 1588-2019 and are briefly described here. Details necessary to utilize IEEE-1588-2008 and IEEE 588-2019 in a manner consistent with the architecture are defined in other Recommendations.

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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.

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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Recommendation ITU-T G.8265.1/Y.1365.1

Precision time protocol telecom profile for frequency synchronization

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 frequency only. The profile is based on the architecture described in [ITU-T G.8265] and definitions described in [ITU-T G.8260]. The first version of the profile specifies the high-level design requirements, modes of operation for the exchange of PTP messages, the PTP protocol mapping, the use of unicast transmission and negotiation, an alternate best master clock algorithm (BMCA), as well as the PTP protocol configuration parameters. The support for mixed unicast/multicast or static unicast modes is for further study.

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

An implementation compliant with this profile can claim compliance with either IEEE Std 1588-2008 [IEEE 1588-2008] or IEEE Std 1588-2019 [IEEE 1588-2019]. Considerations on the use of one or the other profile are provided in Appendix III. Compliance for a specific implementation with either the [IEEE 1588-2008] or [IEEE 1588-2019] versions of the standard should be stated when referring to this 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 (2020), *Synchronization layer functions for frequency synchronization based on the physical layer*.

[ITU-T G.8260] Recommendation ITU-T G.8260 (2020), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8265] Recommendation ITU-T G.8265/Y.1365 (2010), *Architecture and requirements for packet-based frequency delivery*.

[IEEE 1588] Either [IEEE 1588-2008] or [IEEE 1588-2019] depending on the specific implementation. See clause 5 Conventions for more details.

[IEEE 1588-2008] IEEE Std 1588-2008, *Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*.

[IEEE 1588-2019] IEEE 1588-2019, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*.

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3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 packet master clock [ITU-T G.8260]

3.1.2 packet slave clock [ITU-T G.8260]

3.1.3 packet timing signal [ITU-T G.8260]

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BMC	Best Master Clock
BMCA	Best Master Clock Algorithm
EUI	Extended Unique Identifier
GM	Grand Master
NTP	Network Time Protocol
OC	Ordinary Clock
ParentDS	Parent Data Set (terminology used in [IEEE 1588])
LSP	Label Switched Path
MA-L	MAC Address – Large
MA-M	MAC Address – Medium
MA-S	MAC Address – Small
MPLS	Multi-Protocol Label Switching
OUI	Organizationally Unique Identifier
PDV	Packet Delay Variation
PTP	Precision Time Protocol
PTSF	Packet Timing Signal Fail
QL	Quality Level
SDH	Synchronous Digital Hierarchy
SOOC	Slave-Only Ordinary Clock
SSM	Synchronization Status Message
SyncE	Synchronous Ethernet
TLV	Type Length Value
UDP	User Datagram Protocol
VLAN	Virtual Local Area Network

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5 Conventions

Within this Recommendation, the following conventions are used: the term precision time protocol (PTP) refers to the PTP defined in [IEEE 1588]. The term "slave" or "slave clock" refers to a "slave-only ordinary clock" (SOOC) as defined in [IEEE 1588]. A "Telecom Slave" is a device consisting of one or more SOOCs. The term "master" or "packet master" or "packet master clock" refers to a grand master as defined in [IEEE 1588]. PTP messages used within this Recommendation are defined in [IEEE-1588] and are identified using italicized text.

Within this Recommendation, some requirements are stated as requiring compliance to [IEEE 1588]. For implementations compliant to [IEEE 1588-2008], the reference to [IEEE 1588] means compliance to [IEEE 1588-2008]. For implementations compliant to [IEEE 1588-2019], the reference to [IEEE 1588] means compliance to [IEEE 1588-2019]. Some of these references to [IEEE 1588] include a specific clause number. In these cases, the clause number is the same in both [IEEE 1588-2008] and [IEEE 1588-2019]. If the requirements are in different clauses in the two versions of IEEE 1588, then the text of this Recommendation shall include the specific clause for [IEEE 1588-2008] and the specific cause for [IEEE 1588-2019].

6 Use of PTP for frequency distribution

The [IEEE 1588] standard contains the precision time protocol (PTP) that was designed to enable accurate time transfer. It introduces the concept of the "profile", whereby aspects of the protocol may be selected and specified for a particular application. This Recommendation defines the "profile for telecom" applications in order to support the specific architectures described in [ITU-T G.8265].

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].

The [IEEE 1588] telecom profile defined within this Recommendation is intended to be used by applications that need frequency synchronization only. It does not cover applications where there is need for phase alignment and/or time of the day. This profile addresses the case where the PTP masters and slaves will be used in networks where there is no support for the PTP protocol in any intermediate node between the PTP master and the PTP slave.

It is also important to note that the default PTP protocol is based on multicast. This profile uses only the negotiated unicast mode. The use of mixed unicast/multicast operation or static unicast mode is for further study.

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.

6.1 High-level design requirements

[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."

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For operation in the telecom network, some additional criteria are also required to be consistent with standard telecom synchronization practices. With that in mind, high-level objectives for the PTP profile for frequency distribution are:

1) To allow interoperability between PTP master clocks and PTP slave clocks compliant with the profile.

   This means that PTP master clocks compliant with the profile must have the ability to serve multiple PTP slave clocks from different vendors, and slaves require the ability to derive synchronization from one or more masters from different vendors.

2) To permit operation over managed, wide-area packet-based telecom networks.

   This may include networks based on protocols such as Ethernet, IP and multi-protocol label switching (MPLS), and combinations thereof.

3) To define message rates and parameter values consistent with frequency distribution to the required performance for telecom applications.

   Note that the profile does not guarantee meeting performance criteria by itself, but should permit the desired performance, given competently designed equipment operating over a suitably designed and managed packet network.

4) To allow interoperability with existing synchronization networks (such as synchronous Ethernet (SyncE) and synchronous digital hierarchy (SDH)).

   In particular, this means that the profile must define the means to support the transmission of the [ITU-T G.781] quality level (QL) values from packet master clock to packet slave clock, providing full traceability back to a primary reference.

   The QL levels transmitted must be consistent with the existing synchronization practice, and the performance of clocks in the synchronization chain.

5) To allow the synchronization network to be designed and configured in a fixed arrangement.

   Masters should always remain masters, and slaves should always remain slaves. Autonomous re-configuration of the synchronization network (e.g., by use of an automatic process such as the best master clock algorithm described in [IEEE 1588]) should be prevented.

6) To enable protection schemes to be constructed in accordance with standard telecom network practices.

   This should include the following:

   – physical protection, using redundant hardware and master at the same location;
   – geographical protection, using a separate master at a different location. This should include the ability to construct both 1:1 and N:1 protection schemes for packet master clocks.

7) To define the criteria under which slaves switch from one packet master clock to an alternate packet master clock.

   These should be based on standard telecom criteria, i.e., QL value first, then priority values.

8) To permit the operation of existing, standard-based security techniques to help ensure the integrity of the synchronization.

   Examples may include encryption and/or authentication techniques, or network techniques for separating traffic, such as virtual local area networks (VLANs) or label switched paths (LSPs). Note that the profile does not have to define these techniques, but nothing in the profile should prevent the use of them.

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– Slaves should be prevented from connecting to rogue masters (this could be either by an authentication process, or by using network separation to prevent rogue masters from accessing slaves).
– Masters should be prevented from providing service to unauthorized slaves.

Note that it may not be possible to implement some of these requirements without actually degrading the overall level of system performance.

6.2 General description

[IEEE 1588] defines several clock types with varying degrees of PTP message processing. This Recommendation only addresses ordinary clocks as defined in [IEEE 1588]. Boundary and transparent clocks as defined in [IEEE 1588] are out-of-scope for this edition of the Recommendation.

The performance achievable at the slave clock is dependent on several factors. Key issues include the packet delay variation and the stability of the slave clock's internal oscillator. These aspects are out-of-scope for this edition of the Recommendation.

6.2.1 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.

For the purpose of this profile, PTP domains are established by using unicast messaging to ensure isolation of grandmaster clocks. A clock (slave or master) must not take any information from a PTP domain and use it to influence the behaviour of a clock in another PTP domain.

NOTE – There is only a single packet master clock per PTP domain. Within a PTP domain, the domain number will be the same for all clocks.

For example, in Figure 2, there are *N* PTP domains. Each master is utilizing the same PTP domain number. Domain separation is provided by unicast messages.

6.2.2 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"), *Management* and *Signaling*.

6.3 PTP modes

[IEEE 1588] describes several modes of operation between a master and a slave. 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

PTP is a protocol designed to deliver time synchronization. In order to compensate for the propagation delay of messages through the network, messages are sent in each direction allowing the round-trip delay to be measured. The one-way delay is then estimated as being half the round-trip delay. This is known as two-way operation. However, when PTP is used to deliver frequency only, two-way operation is not required, since the propagation delay of the synchronization messages does not need to be compensated. For frequency distribution, the use of a one-way operation is therefore possible.

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