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Packet over Transport aspects – Synchronization, quality
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Architecture and requirements for packet-based time and phase distribution

Recommendation ITU-T G.8275/Y.1369

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Recommendation ITU-T G.8275/Y.1369

Architecture and requirements for packet-based time and phase distribution

Summary

Recommendation ITU-T G.8275/Y.1369 describes the architecture and requirements for packet-based time and phase distribution in telecom networks. The architecture described is mainly applicable to the use of IEEE 1588. Details necessary to utilize IEEE 1588 in a manner consistent with the architecture are defined in other Recommendations.

History

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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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Introduction

Recommendation ITU-T G.8275/Y.1369 describes the general architecture of time and phase distribution using packet-based methods. This Recommendation forms the base architecture for the development of telecom profiles for time and phase distribution. The architecture described covers the case where protocol interaction is at all nodes, between a packet master clock and a packet slave clock. Details of the necessary profiles are described in other Recommendations.

Recommendation ITU-T G.8275/Y.1369

Architecture and requirements for packet-based time and phase distribution

1 Scope

This Recommendation describes the general architecture of time and phase distribution using packet-based methods. This version of the Recommendation focuses on the distribution of time and phase using the standard for precision time protocol (PTP) [IEEE 1588]. The requirements and architecture form a base for the specification of other functionalities that are needed to achieve packet-based time and phase distribution in a carrier environment. The architecture described covers the case where protocol interaction is at all nodes, between a packet master clock and a packet slave clock. Details of the necessary profiles are described in other Recommendations.

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.805] Recommendation ITU-T G.805 (2000), *Generic functional architecture of transport networks*.
- [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.8261] Recommendation ITU-T G.8261/Y.1361 (2013), *Timing and synchronization aspects in packet networks*.
- [ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (2015), *Timing characteristics of a synchronous Ethernet equipment slave clock*.
- [ITU-T G.8264] Recommendation ITU-T G.8264/Y.1364 (2017), *Distribution of timing information through packet networks*.
- [ITU-T G.8265] Recommendation ITU-T G.8265/Y.1365 (2010), *Architecture and requirements for packet-based frequency delivery*.
- [ITU-T G.8265.1] Recommendation ITU-T G.8265.1/Y.1365.1 (2014), *Precision time protocol telecom profile for frequency synchronization*.
- [ITU-T G.8271] Recommendation ITU-T G.8271/Y.1366 (2016), *Time and phase synchronization aspects of packet networks*.
- [ITU-T G.8271.1] Recommendation ITU-T G.8271.1/Y.1366.1 (2013), *Network limits for time synchronization in packet networks*.
- [IEEE 1588] IEEE STD 1588 (2008), *Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*.

3 Definitions

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

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APTS	Assisted Partial Timing Support
APTSC	Assisted Partial Timing Support Clock
BC	Boundary Clock
BMCA	Best Master Clock Algorithm
EEC	Synchronous Ethernet Equipment Clock
ESMC	Ethernet Synchronization Messaging Channel
GM	Grandmaster
GNSS	Global Navigation Satellite System
HRM	Hypothetical Reference Model
IWF	Inter-working Function
LTE	Long Term Evolution
NTP	Network Time Protocol
OTN	Optical Transport Network
PDV	Packet Delay Variation
PRC	Primary Reference Clock
PRTC	Primary Reference Time Clock
PTP	Precision Time Protocol
PTS	Partial Timing Support
QL	Quality Level
SDH	Synchronous Digital Hierarchy
SEC	SDH Equipment Clock
SF	Signal Fail
SSM	Synchronization Status Message
SSU	Synchronization Supply Unit
T-BC	Telecom Boundary Clock
T-GM	Telecom Grandmaster
T-TC	Telecom Transparent Clock
T-TSC	Telecom Time Slave Clock
TC	Transparent Clock
UTC	Coordinated Universal Time
WCDMA	Wideband Code Division Multiple Access

5 Conventions

Within this Recommendation, the term PTP refers to the PTP version 2 protocol defined in [IEEE 1588].

6 General introduction to packet-based time/phase distribution

The distribution of accurate time and phase is necessary to support certain telecom-based services and in particular the underlying infrastructure. While traditional network synchronization has relied on the accurate distribution of frequency, evolving wireless networks require the distribution of accurate time and phase.

As the network evolves from a primarily TDM-based network infrastructure to one using packet-based technology, the ability to distribute synchronization is also changing.

In order to enable timing distribution in packet-based networks, the ITU-T developed specifications ([ITU-T G.8261], [ITU-T G.8262] and [ITU-T G.8264]) for synchronous Ethernet, which allowed the use of the Ethernet physical layer to be used as a mechanism to distribute frequency analogous to the methods used with synchronous digital hierarchy (SDH)-based network synchronization. In this regard, synchronous Ethernet, by appropriate specification of network equipment clocks provided support for the existing frequency-based synchronization network over both existing TDM and new packet-based technology.

In the absence of the ability to utilize the physical layer, the ITU also developed Recommendations covering frequency distribution using packet-based methods such as PTP and network time protocol (NTP). The use of packet-based methods also enabled new frequency synchronization scenarios to be considered. These, as well as other aspects specific to packet-based frequency distribution, resulted in the development of an architectural specification [ITU-T G.8265].

This Recommendation describes the architecture for packet-based time and phase distribution.

6.1 Requirements for packet-based time and phase distribution

Packet-based mechanisms for time and phase distribution must meet the following five requirements:

- 1) mechanisms must be specified to allow interoperability between the various phase/time clocks defined in this architecture;
- 2) mechanisms must permit consistent operation over managed wide area telecom networks;
- 3) packet-based mechanisms must allow the synchronization network to be designed and configured in a fixed arrangement;
- 4) protection schemes used by packet-based systems must be based on standard telecom operational practice and allow telecom time slave clocks (T-TSC) the ability to take phase and time from multiple geographically separate telecom grandmaster (T-GM) clocks;
- 5) phase/time reference source selection based on received phase/time traceability and local priority should be permitted. Automatic establishment of the phase/time synchronization network topology may also be possible.

7 Architecture of packet-based time/phase distribution

In contrast to physical layer synchronization, where the significant edges of a data signal define the timing content of the signal, packet-based methods rely on the transmission of dedicated "event packets". These "event packets" form the significant instants of a packet timing signal. The timing of these significant instants is precisely measured relative to a master time source, and this timing information is encoded in the form of a time stamp, which is a machine-readable representation of a specific instance of time. The time stamp is generated via a packet master function and is carried over a packet network to a packet slave clock.

A protocol is used between the master and the slave clocks in order to adjust for transmission and other delays, resulting in both the master and slave clocks having the same time reference.

As time is the integral of frequency, the time stamps can also be used to derive frequency. This case is covered in [ITU-T G.8265] and [ITU-T G.8265.1].

7.1 Packet-based time and phase distribution

A time reference is initially obtained from a primary reference time clock (PRTC). If the time across the system is required to be referenced to coordinated universal time (UTC) or to some other universal standard source of time, the PRTC itself may require a time reference input such as a global navigation satellite system (GNSS) signal.

For the purposes of time and phase synchronization transport, the packet master delivers its reference to the packet slave clocks using a packet timing signal (see [ITU-T G.8260]).

In order to achieve better accuracy, protocol-level timing support may be used at the various network nodes. Specifically for the [IEEE 1588] PTP protocol, these intermediate devices are termed boundary clocks (BCs) or transparent clocks (TCs).

The architecture described in this Recommendation describes two cases; the first case is where timing support is provided by all nodes in the network (e.g., telecom boundary clocks (T-BCs)) with physical layer frequency support ("full timing support to the protocol level" (see [ITU-T G.8260])) and the second case is where intermediate nodes do not provide timing support, but timing support is provided by GNSS at the network edge, with PTP acting as a backup. This is termed assisted partial timing support (APTS). The node providing support at the edge of the network is called an assisted partial timing support clock (APTSC).

Other architectures where not all of the nodes need to provide timing support by participating in the timing protocol are termed "partial timing support to the protocol level" (PTS) (see [ITU-T G.8260]). Some additional considerations for this topic are documented in Appendix I.

In both types of architectures, physical layer frequency support may be available to stabilize the operation of the T-BCs or telecom transparent clocks (T-TCs).

The time-transfer protocol operating between the nodes allows the same time to be recovered or corrected at all nodes participating in the timing protocol, subject to some degradation (δ).

In some deployments, especially in the access part of the network, it may be convenient to provide timing support from the protocol via T-TC functions. One typical example is in the case of microwave connections.

NOTE 1 – The T-TCs are typically connected in tree architectures. Rings composed entirely of T-TCs can raise issues in terms of PTP packets loops.

The general network topology for time/phase distribution from a packet master clock PRTC to a T-TSC is shown in Figure 1. The synchronization flow is from the master to slave, although the timing messages will flow in both directions. Individual nodes are T-BCs or T-TCs in the case of full support from the network.

NOTE 2 – The following figure does not imply any hypothetical reference model (HRM).

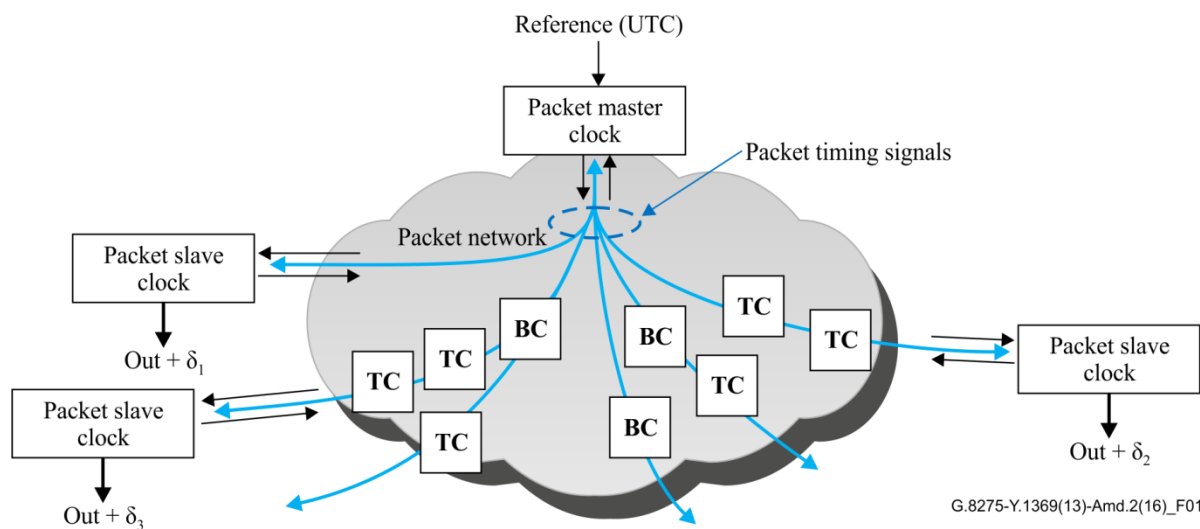


Figure 1 – Time distribution to slave clocks

Additional aspects related to performance are also covered in [ITU-T G.8271] and [ITU-T G.8271.1].

7.2 Time/phase protection aspects

Protection is required to optimize the performance of services. Protection is defined as mechanisms that allow maintaining the phase/time reference delivered to the end application (e.g., a base station) to an acceptable level during failure events. It includes redundancy of the phase/time primary reference sources (time-plane rearrangement) and phase/time holdover (time-plane holdover). Protection is described in the next sections in terms of protection of the packet master/PRTC and protection of the packet slave.

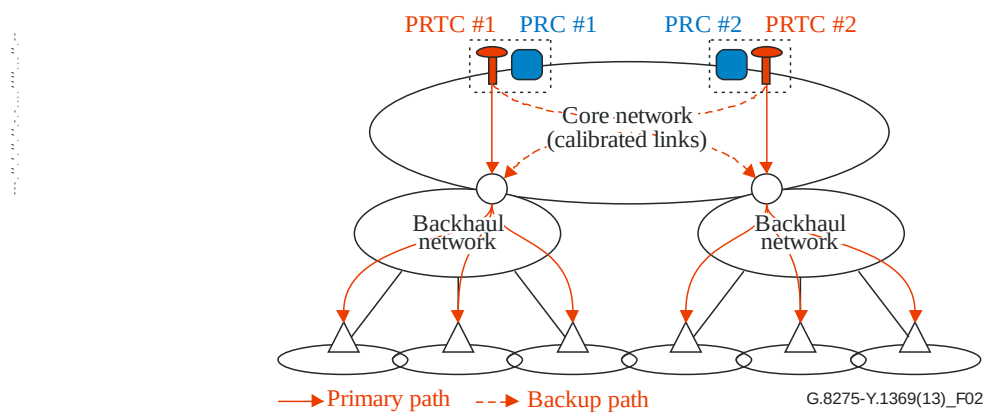
7.2.1 Packet master protection

PRTC location

When considering phase/time distribution, the PRTC functions can be located at different positions, depending on the overall architecture that the network operator wishes to follow. However, these can be summarized into the four generic locations described in this clause.

These are the main scenarios, others may be considered.

Case A: centralized PRTC collocated with a primary reference clock (PRC)



NOTE – T-GM are connected to the PRTC in this architecture

Figure 2 – Architecture with centralized PRTC functions collocated with PRC

