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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

Architecture and requirements for packet-based time and phase distribution

Recommendation ITU-T G.8275/Y.1369

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ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
Ethernet over Transport aspects	G.8000–G.8099
MPLS over Transport aspects	G.8100–G.8199
Synchronization, quality and availability targets	**G.8200–G.8299**
Mobile network transport aspects	G.8300–G.8399
Service Management	G.8600–G.8699
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

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.

This revision of Recommendation ITU-T G.8275 (2017) provides the following updates:

– Common annex and appendix material to ITU-T G.8275.1 and ITU-T G.8275.2 added as Annex C, Annex D and Appendix VIII.

History

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

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

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

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

Table of Contents

Page

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 or only a subset of the 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 (2020), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8261] Recommendation ITU-T G.8261/Y.1361 (2019), *Timing and synchronization aspects in packet networks*.

[ITU-T G.8261.1] Recommendation ITU-T G.8261.1/Y.1361.1 (2012), *Packet delay variation network limits applicable to packet-based methods (Frequency synchronization)*.

[ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (2018), *Timing characteristics of a synchronous equipment slave clock*.

[ITU-T G.8263] Recommendation ITU-T G.8263/Y.1363 (2017), *Timing characteristics of packet-based equipment clocks*.

[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 (2020), *Time and phase synchronization aspects of telecommunication networks*.

[ITU-T G.8271.1] Recommendation ITU-T G.8271.1/Y.1366.1 (2020), *Network limits for time synchronization in packet networks with full timing support from the network*.

[ITU-T G.8272] Recommendation ITU-T G.8272/Y.1367 (2018), *Timing characteristics of primary reference time clocks*.

[ITU-T G.8275.1] Recommendation ITU-T G.8275.1/Y.1369.1 (2020), *Precision time protocol telecom profile for phase/time synchronization with full timing support from the network*.

[ITU-T G.8275.2] Recommendation ITU-T G.8275.2/Y.1369.2 (2020), *Precision time protocol telecom profile for phase/time synchronization with partial timing support from the network*.

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

3 Definitions

3.1 Terms defined elsewhere

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

cnPRTC Coherent Network PRTC

DS Data Set

EEC Synchronous Ethernet Equipment Clock

ePRTC Enhanced PRTC

ESMC Ethernet Synchronization Messaging Channel

FTS Full Timing Support

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

PPS Pulse Per Second

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
TAI	International Atomic Time
T-BC	Telecom Boundary Clock
T-GM	Telecom Grandmaster
T-TC	Telecom Transparent Clock
T-TSC	Telecom Time Slave Clock
TC	Transparent Clock
ToD	Time of Day
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" (FTS) (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).

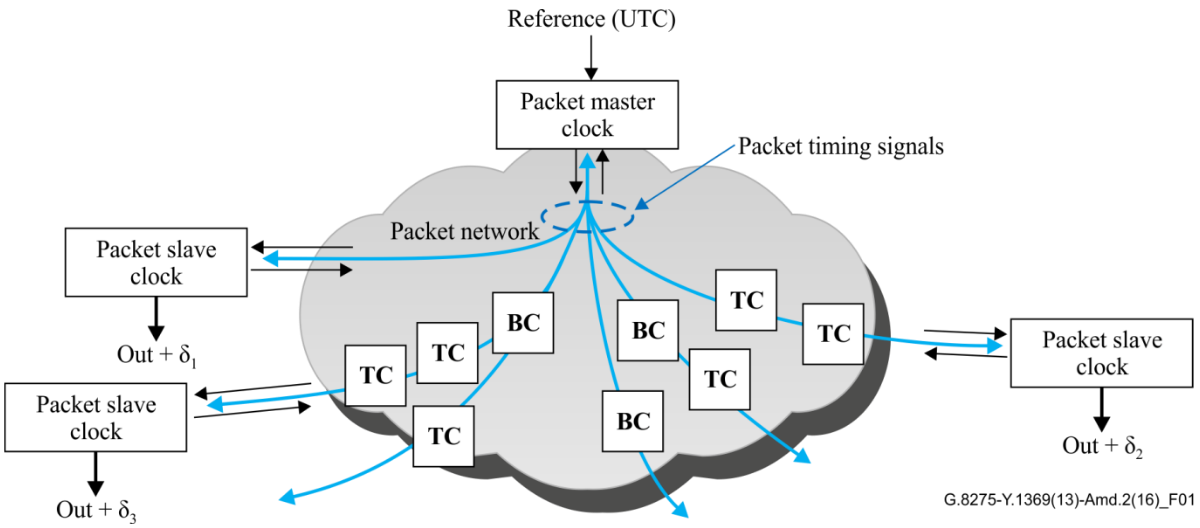


Figure 1 – Time distribution to slave clocks

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.

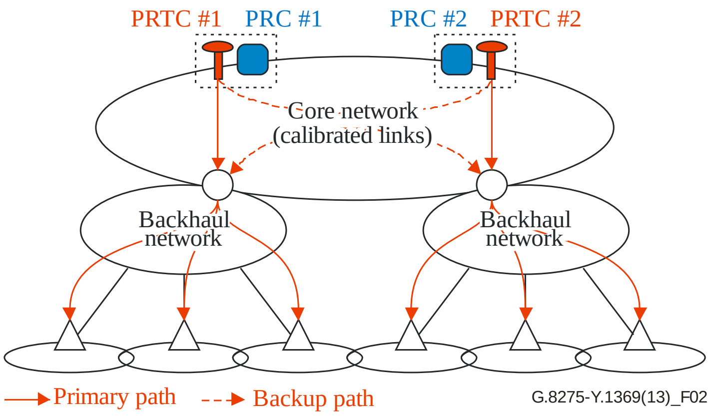
7.2.1 Packet master protection

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

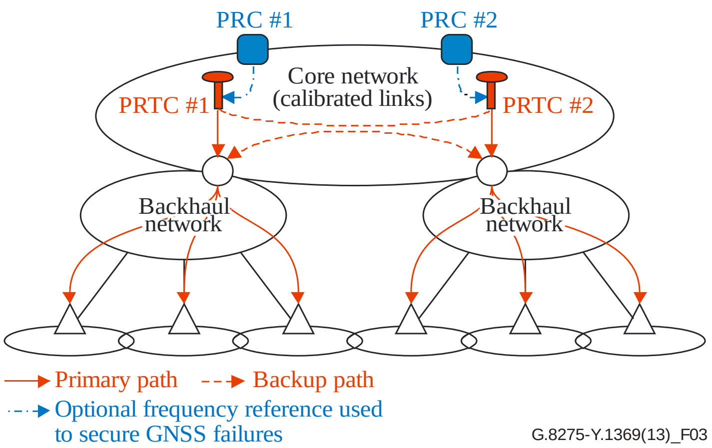
Figure 2 – Architecture with centralized PRTC functions collocated with PRC

Figure 2 only shows a primary path to the base stations, other protection mechanisms may be present, but are not shown. Some details may be hidden.

This architecture is compatible with PRTC redundancy (e.g., in order to protect against GNSS failures): in case one of the PRTCs fails, another PRTC would deliver the reference to the nodes that have previously been receiving the reference from the PRTC in failure.

This architecture requires the links of the core network to be properly calibrated to avoid the accumulation of excessive time error due to link asymmetry.

Case B: centralized PRTC not collocated with PRC



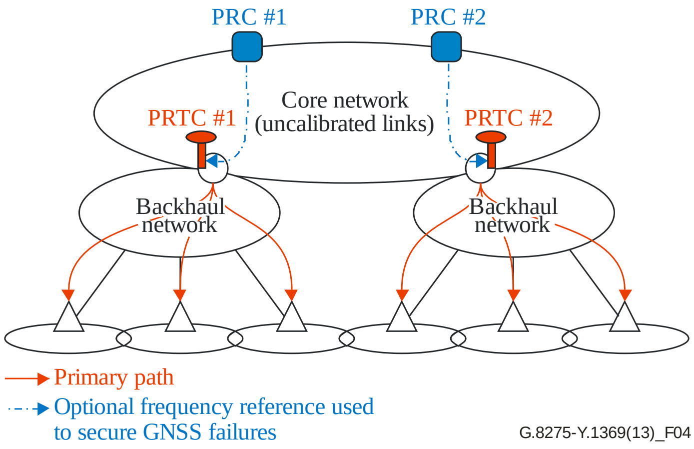
NOTE – T-GM are connected to the PRTC in this architecture

Figure 3 – Architecture with centralized PRTC functions not collocated with PRC

The architecture, shown in Figure 3, is also compatible with PRTC redundancy. In addition, the PRTC function may receive a PRC-traceable physical layer frequency reference (e.g., synchronous Ethernet) in order to provide additional protection against GNSS failures, or to participate in the generation of the reference provided by the PRTC under nominal conditions.

This architecture also requires the links of the core network to be properly calibrated in order to avoid the accumulation of excessive time error due to link asymmetry.

Case C: distributed PRTC in aggregation sites



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

Figure 4 – Architecture with PRTC functions distributed in aggregation sites

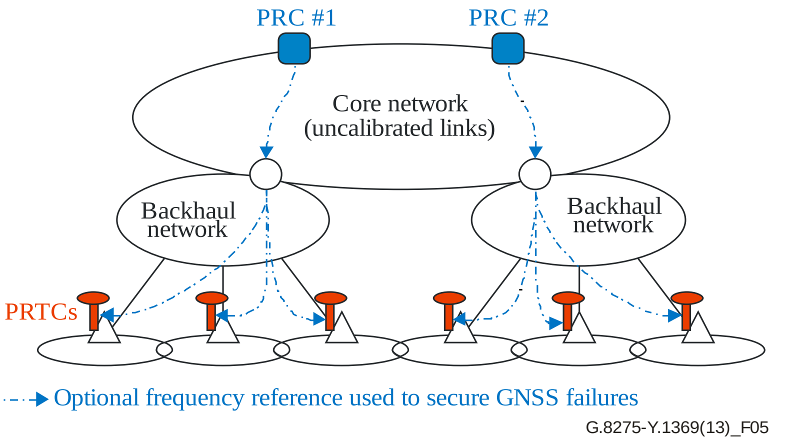
In this architecture, shown in Figure 4, the PRTC function is located in an aggregation site; typically, a GNSS receiver is added to one of the last synchronization supply units (SSUs) of the physical layer frequency chain. This implies the deployment of a higher number of GNSS receivers than in the centralized PRTC architecture. However, the advantage is that the links of the core network do not have to be calibrated to compensate for the link asymmetry.

PRTC redundancy schemes are not always compatible with this architecture, especially when considered between different aggregation sites; indeed, there is in general no direct connectivity between these aggregation sites.

When PRTC redundancy is considered between different aggregation sites, it implies that some nodes of the core network would support PTP clocks (e.g., T-BC to be supported by the nodes between the PRTC functions), as well as proper calibration of some of the links of the core network.

When PRTC redundancy is not used, it is recommended that GNSS failures would be secured by other means; typically, the use of a PRC-traceable physical layer frequency reference delivered to the PRTC function allows extending the phase/time holdover period during GNSS failures.

Case D: distributed PRTC at the cell sites



NOTE – There is normally no T-GM connected to the PRTC in this architecture

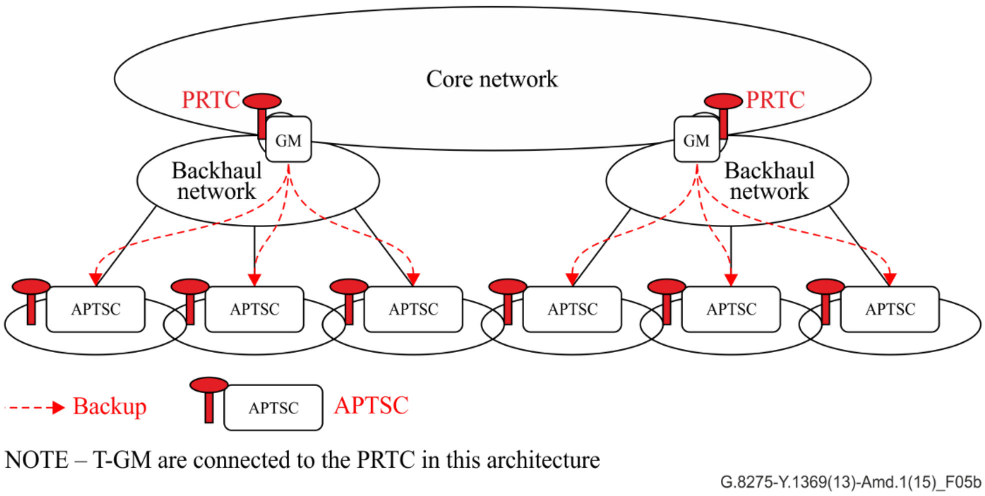
Figure 5a – Architecture with PRTC functions distributed at cell sites

In this architecture, shown in Figure 5a, the PRTC function is now located directly at the cell site; typically, a GNSS receiver is directly connected to the base stations. This implies deployment of a higher number of GNSS receivers than in the "centralized PRTC" and "distributed PRTC in an aggregation site" architectures. However, the advantage is that the links of both the core and backhaul networks do not have to be calibrated to compensate for the link asymmetry.

PRTC redundancy schemes are not compatible with this architecture between different cell sites. It is therefore recommended that GNSS failures would be secured by other means; typically, the use of a PRC-traceable physical layer frequency reference delivered to the PRTC function allows extending the phase/time holdover period during GNSS failures.

The use of T-GM to distribute phase/time between different cell sites is for further study.

Case E: APTSC at the cell sites with distributed PRTC+GM protection in aggregation sites



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

Figure 5b – APTS architecture with PRTC functions distributed in aggregation sites

In this architecture, shown in Figure 5b, the APTSC function is located directly at the cell site; in addition, PRTC+GMs are located at the aggregation sites and distribute PTP streams to the APTSCs. These PTP streams are used by the APTSC in case of a PRTC/GNSS outage. This architecture implies deployment of a higher number of GNSS receivers than in the "centralized PRTC" architectures.

However, PTP unaware or partially aware networks can be kept as short as possible to decrease the asymmetry and packet delay variation (PDV) introduced by the network.

Case F: APTSC at the cell sites with distributed PRTC protection at cell sites

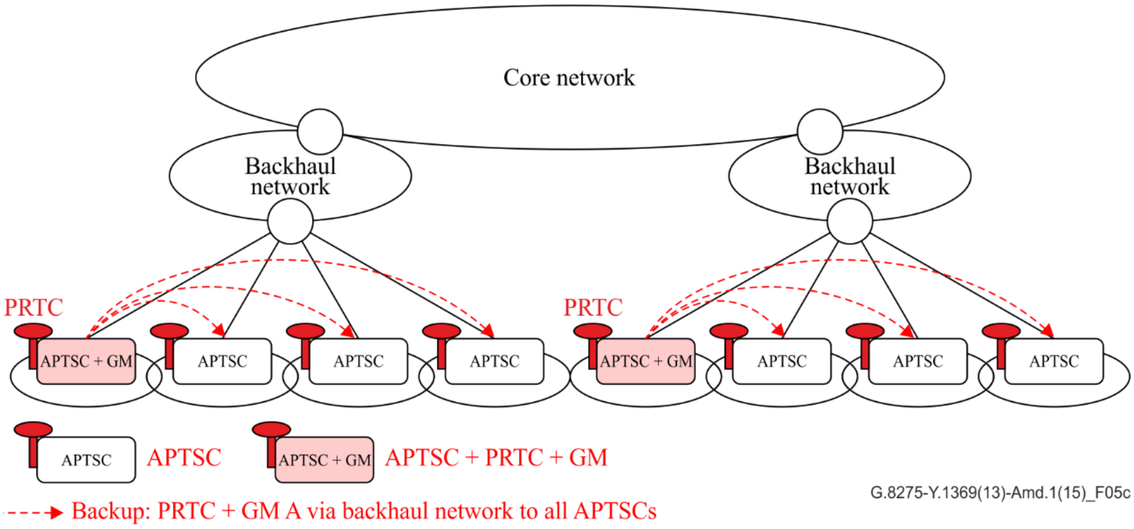


Figure 5c – APTS architecture with PRTC+GM functions distributed at cell sites

In this architecture, shown in Figure 5c, the APTSC function is located directly at the cell site; in addition, GMs are located at selected cell sites and distribute PTP streams to the adjacent APTSCs. These PTP streams are used by the APTSC in case of a PRTC/GNSS outage. This architecture implies deployment of a higher number of GNSS receivers than in the "centralized PRTC" architectures. However, PTP unaware or partially aware networks can be kept as short as possible to decrease the asymmetry and PDV introduced by the network. In addition, the GNSS signal available to the APTSC in the cell site is used by the collocated GM.

Applicable PRTC models depending on PRTC location

The first PRTC model, illustrated in Figure 6, where no physical layer frequency input is present, may be applicable to Case A introduced earlier. It corresponds to the case where PRTC and PRC functions are merged in the same equipment and coherency between the frequency and phase/time planes is therefore ensured.

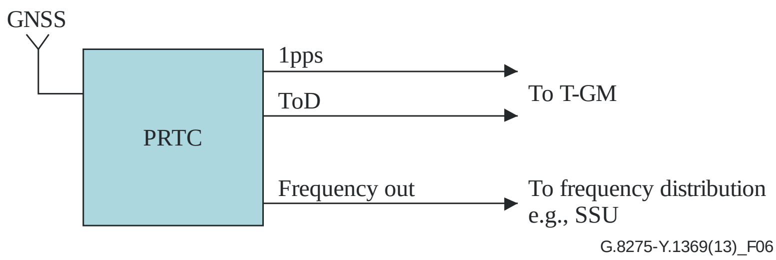


Figure 6 – PRTC model with no physical layer frequency input

NOTE – In addition to being connected to a T-GM, a PRTC may be connected to a T-BC by the 1pps+ToD interface. This is useful for some applications such as achieving protection in ring network, see Appendix II.

The second PRTC model, illustrated in Figure 7, where a physical layer frequency input is present and may be applicable to the Cases A, B, C, and D introduced earlier. It corresponds to the case where PRTC and PRC functions are implemented in separate equipment and coherency between the frequency and phase/time planes is not always ensured.

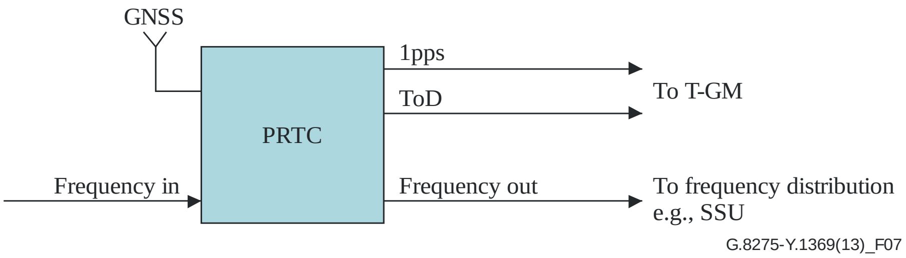


Figure 7 – PRTC model with a physical layer frequency input

NOTE − In addition to being connected to a T-GM, a PRTC may be connected to a T-BC by the 1pps+ToD interface. This is useful for some applications such as achieving protection in ring network, see Appendix II.

The case where the PRTC and T-GM are combined is shown in Figure 8. The Ethernet interface that supplies PTP may also supply frequency (i.e., it operates as a synchronous Ethernet interface).

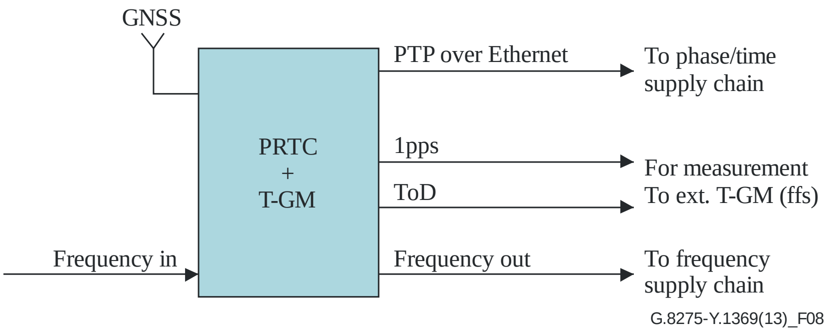


Figure 8 – Combined PRTC and T-GM

There are other network architectures under study based on an enhanced PRTC (ePRTC) that provide the ability to maintain network-wide time accuracy (see Appendix VI). Additional details are for further study.

7.2.2 Packet slave protection

This clause deals with the various schemes that may be considered for providing redundancy in the distribution of a time synchronization reference.

Three protection scenarios for phase/time synchronization of the packet slave are described. The scenarios are:

1) phase/time long-term holdover with physical layer frequency synchronization support;
2) switching to a backup reference with physical layer frequency synchronization support;
3) switching to a backup reference without physical layer frequency synchronization support.

Protection scenarios 2 and 3 involve time-plane rearrangements, while protection scenario 1 involves time-plane holdover. In protection scenario 2, the frequency reference during the rearrangement is provided via physical layer support, i.e., synchronous Ethernet. In protection scenario 3, the frequency reference during the rearrangement is provided via the end application clock in holdover. In protection scenario 1, the phase/time holdover is provided by physical layer support.

The three scenarios are described in the following clauses.

7.2.2.1 Protection scenario 1

Protection scenario 1 involves holdover with physical layer frequency support (i.e., synchronous Ethernet), where the period of holdover is generally much longer than the period of the rearrangement of protection scenario 2 (see clause 7.2.2.2). Three sub-scenarios may be considered for protection scenario 1. It is assumed that there is no backup master in this case:

1) scenario 1.1: The synchronous Ethernet reference used during holdover is available at the end application;

2) scenario 1.2: The synchronous Ethernet reference used during holdover is available at the PRTC, and it is the PRTC that enters holdover by losing its GNSS reference. The end application receives its timing from the PRTC via PTP;

3) scenario 1.3: The synchronous Ethernet reference used during holdover is available at the PRTC, and it is the PRTC that enters holdover by losing its GNSS reference. The end application is collocated with and receives its timing directly from the PRTC.

Three holdover periods are of interest for protection scenarios 1.1, 1.2 and 1.3:

1) short holdover period, on the order of minutes (e.g., up to 5 minutes, maximum);

2) long holdover period, on the order of hours (e.g., up to 8 hours);

3) very long holdover periods, on the order of days (e.g., up to 3 days).

The short holdover period is assumed to cover cases where the GNSS signals become unavailable for a short period of time. The long holdover period is assumed to cover cases where the GNSS signals remain unavailable for a longer period of time, possibly without the need for an on-site operator intervention. The very long holdover period covers the cases of very long failures, for which an on-site operator intervention is necessary.

Protection scenario 1.1 is illustrated in Figure 9. In this protection scenario, the phase/time synchronization path fails and the end application (e.g., the base station) is informed that the reference signal is no longer traceable to a PRTC so that it would switch to holdover. Relying on only a free-running local clock, even of good quality, may not allow addressing the long and very long holdover periods mentioned above. Instead, the local clock in the end application must be locked to an accurate and stable physical layer frequency reference, such as synchronous Ethernet.

The phase/time long-term holdover function is assumed to be supported in a PTP clock capable of adequately filtering the noise that may be present on the synchronous Ethernet reference. The same function can be used in a base station receiving both a 1PPS input signal and a synchronous Ethernet reference. During the holdover period, any timing signal delivered to the application by PTP is not used.

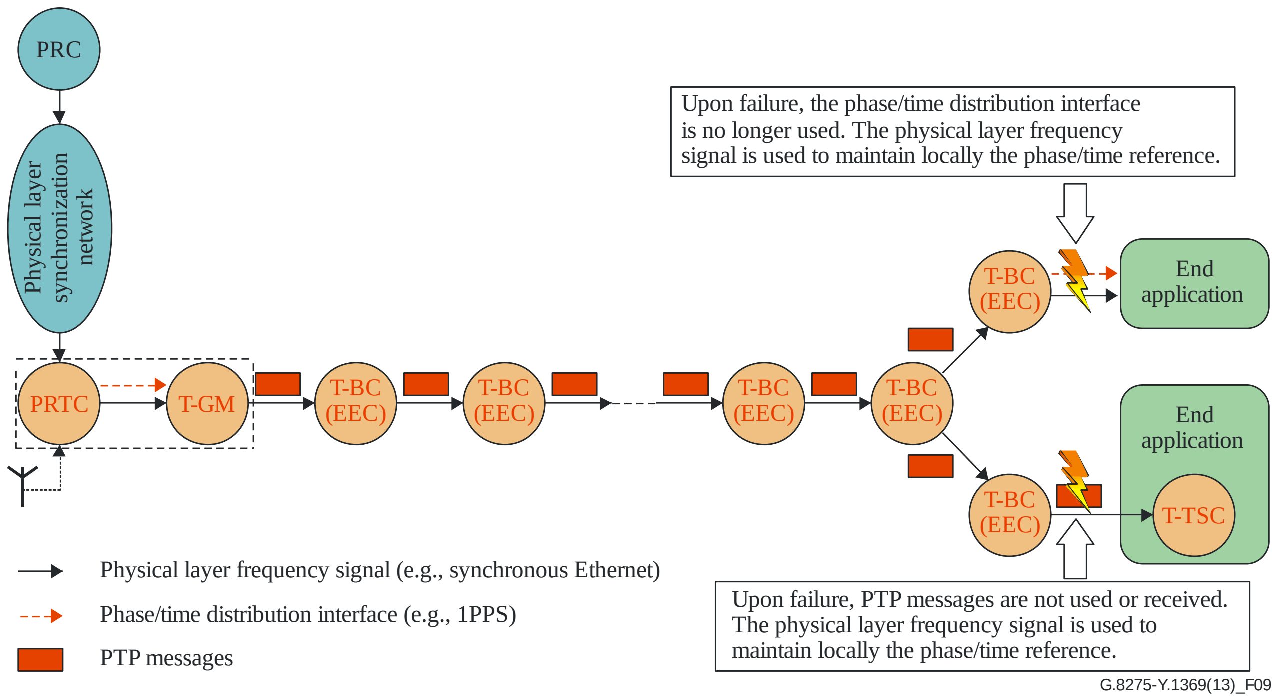


Figure 9 – Illustration of protection scenario 1.1 at the T-TSC (phase/time long-term holdover at the T-TSC embedded in the end application)

Protection scenario 1.2 is illustrated in Figure 10. In this case, the phase/time long-term holdover function is supported by the PRTC/T-GM. Like protection scenario 1.1, this holdover function includes a clock that is capable of providing a high-quality frequency reference (e.g., high quality local oscillator or synchronous Ethernet equipment clock (EEC)). When the PRTC connected to the T-GM has lost its reference (e.g., GNSS signal is lost), the PRTC may continue to deliver time synchronization using this frequency reference.

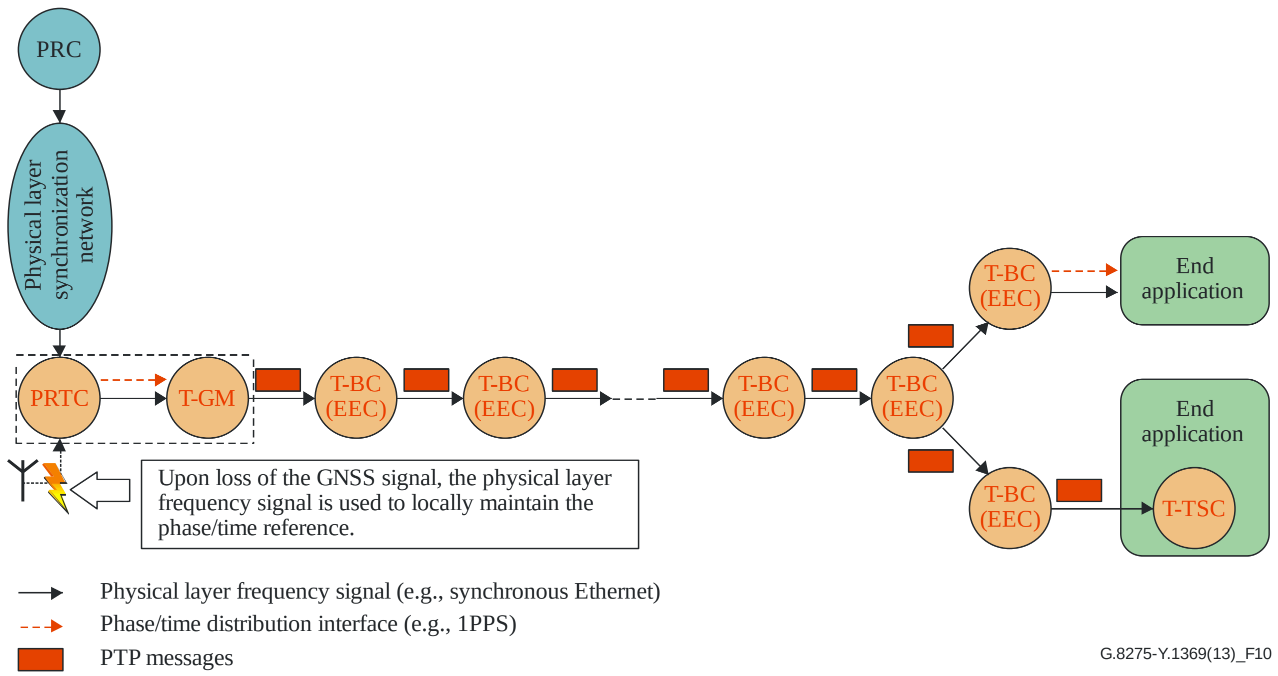


Figure 10 – Illustration of protection scenario 1.2 at the PRTC/GM, (phase/time long-term holdover at the PRTC/GM, with the PRTC/GM not collocated with the end application)

Protection scenario 1.3 is illustrated in Figure 11. In this case, as in protection scenario 1.2, the phase/time long-term holdover function is supported by the PRTC, which is also assumed to have a good oscillator embedded, for instance, in case of problems with the GNSS signals reception. When the PRTC has lost its reference (e.g., GNSS signal is lost), the PRTC may continue to deliver time synchronization either using the internal oscillator or using external frequency synchronization reference (e.g., synchronous Ethernet). However, now the PRTC is collocated with the end application.

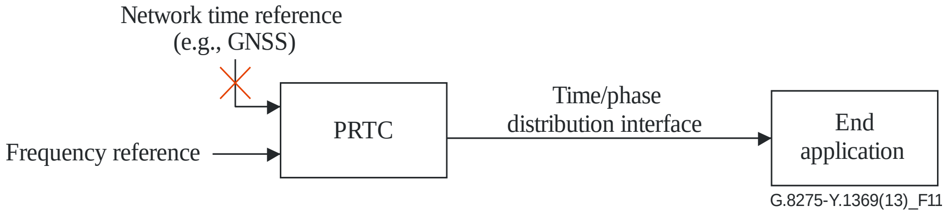


Figure 11 – Illustration of protection scenario 1.3 at the PRTC (phase/time long-term holdover at the PRTC, with the PRTC collocated with the end application)

7.2.2.2 Protection scenario 2

Protection scenario 2 is illustrated in Figure 12. In this protection scenario, a T-BC in the chain detects a failure in the primary PTP phase/time synchronization path, e.g., it stops receiving PTP time-stamp messages on its slave port or information on the signal indicates a degraded reference. This T-BC informs the downstream PTP clocks (T-BC, T-TSC) that the reference is no longer traceable to a PRTC. This triggers the best master clock algorithm (BMCA) and a new PTP path is determined.

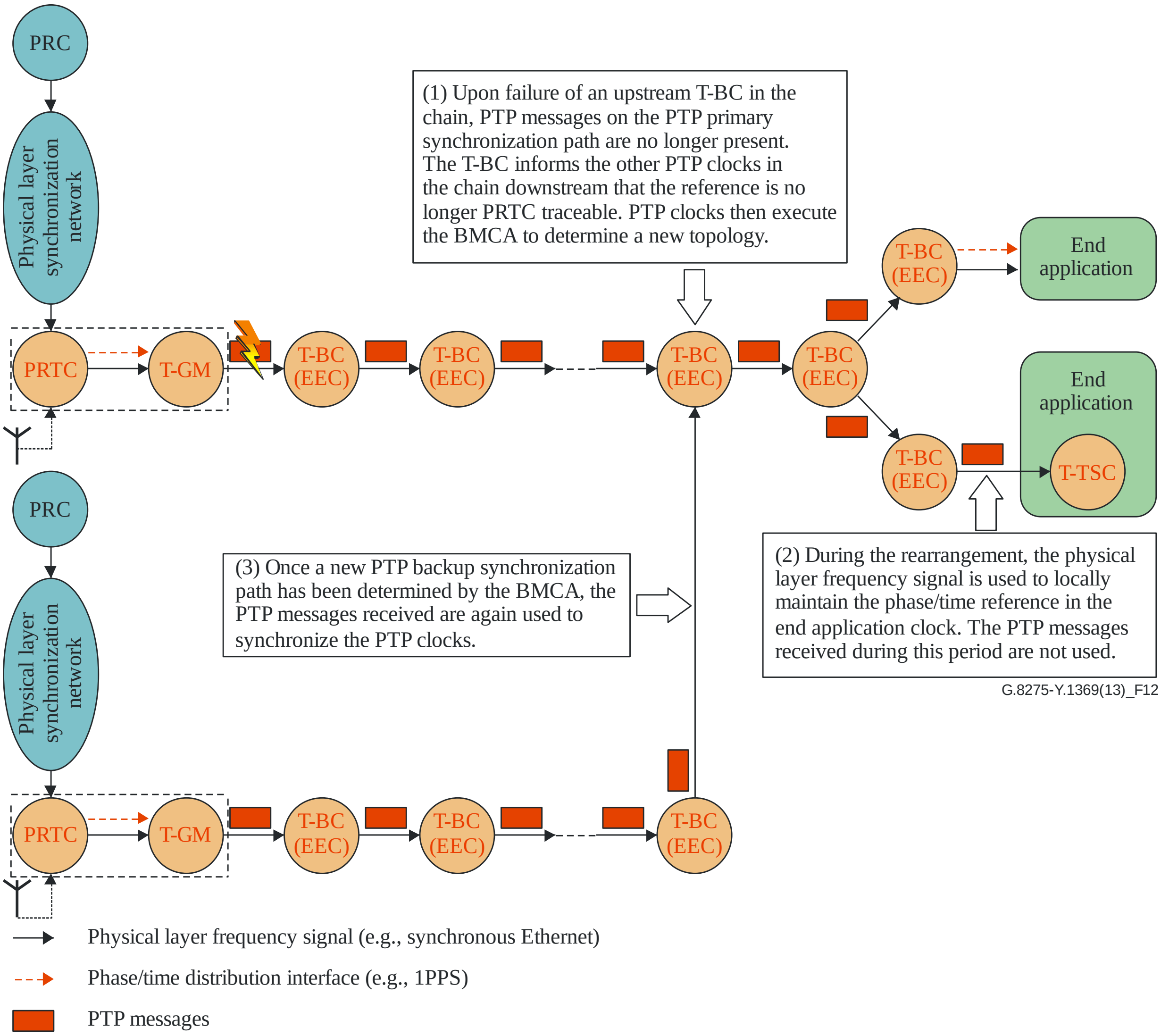


Figure 12 – Illustration of protection scenario 2 (switching to a backup reference with physical layer frequency synchronization support)

Immediately after the failure has been detected, the end application (e.g., a base station) is therefore informed that the reference signal is no longer traceable to a PRTC and switches to holdover. It may take some time to propagate this information down the chain, depending on the position of the T-BC which has detected the failure. The local clock in the end application is locked to an accurate and stable physical layer frequency reference, such as synchronous Ethernet, since this support is used.

The BMCA is run to determine a new PTP synchronization path.

The phase/time holdover function is assumed to be supported in the T-TSC embedded in the base station. The same function can be used in a base station receiving both a 1PPS input signal and a synchronous Ethernet reference (in this case, the 1PPS signal should be squelched during the failure).

The T-BC must be able to inform about the loss of PRTC traceability.

7.2.2.3 Protection scenario 3

Protection scenario 3 is illustrated in Figure 13. In this protection scenario, a T-BC in the chain detects a failure in the primary PTP phase/time synchronization path, e.g., it stops receiving PTP time-stamp messages on its slave port or information on the signal indicates a degraded reference. This T-BC informs the other PTP clocks of the chain downstream (T-BC, T-TSC) that the reference is no longer traceable to a PRTC.

It may take some time for the information of the failure to propagate down the chain, depending on the position of the T-BC which detected the failure. Once the T-TSC is informed of the upstream failure, it enters holdover.

The holdover in the end application is based on a local clock of good quality not locked to an external reference, since the physical layer frequency synchronization support is not available. During the holdover period, any timing signals delivered to the end application by PTP are not used.

The BMCA is run in order to determine a new PTP synchronization path.

The holdover function is assumed to be supported in the T-TSC embedded in the base station. The same function can be used in a base station receiving a 1PPS input signal (in this case, the 1PPS signal should be squelched during the failure).

The T-BC must be able to inform about the loss of PRTC traceability.

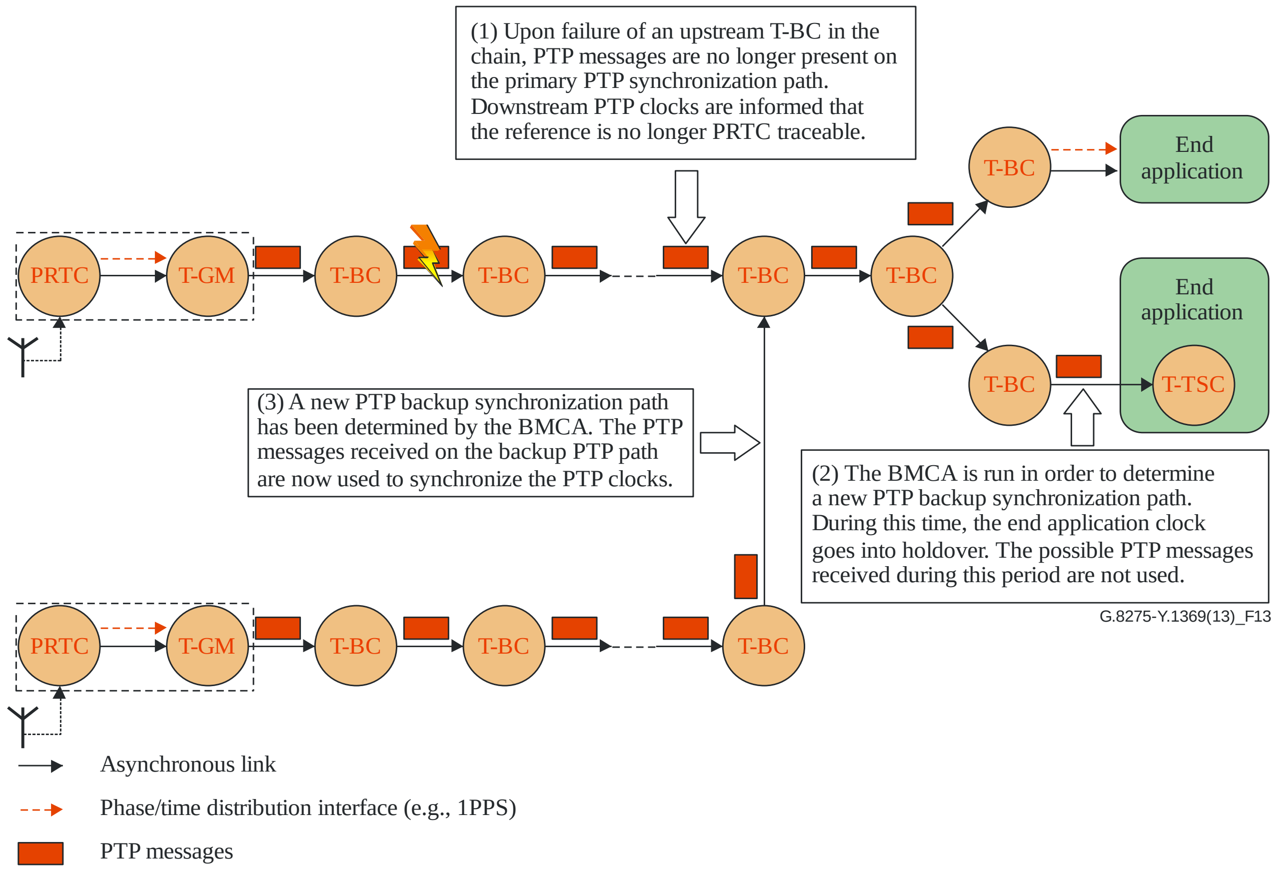


Figure 13 – Illustration of protection scenario 3 (switching to a backup reference without physical layer frequency synchronization)

7.3 Packet network partitioning

Operation over multiple domains may need to be considered, especially in the case of the mobile backhaul. This is for further study.

8 Security aspects

Unlike traditional timing streams where frequency is carried over the physical layer, packet-based timing streams may be observed at different points in the network. There may be cases where timing packets flow across multiple network domains which may introduce specific security requirements. There may also be aspects of security that may be related to both the network (e.g., authentication and/or authorization) and to the PTP protocol itself.

It is important to permit the operation with existing standards-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 lable-switched paths (LSPs).

It may not be possible to implement some of these requirements without actually degrading the overall level of timing or system performance.

Certain aspects of security are for further study; however, some critical aspects are:

– 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);

– a BC port that is connected to a "customer" must never enter a slave state;

– masters should be prevented from providing services to unauthorised slaves.

9 Management aspects

Network management aspects are for further study.

Annex A

Time/phase models based on ITU-T G.805

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

[ITU-T G.8264] provided descriptions of timing flows related to packet network synchronization. Specifically, timing flows were shown that cover the case of circuit emulation and physical layer frequency synchronization based on synchronous Ethernet.

This annex shows the timing flows appropriate to packet-based time mechanisms.

Network models help to ensure that interoperable systems can be developed. What follows is a discussion of [ITU-T G.805] as a modelling technique, as this is what was used in the initial development of [ITU-T G.8264]. [ITU-T G.805] has been used for many years to describe the behaviour of TDM systems. Since the development of [ITU-T G.8264], further work has been undertaken within ITU-T to extend the models to cover packet networks. However, for the purposes here, it is sufficient to refer to the [ITU-T G.805] models.

[ITU-T G.805] provides the modelling "language" to describe transport networks and it describes at the high level, the functional blocks that form a transport network. These define the overall "architecture" in a manner that is implementation independent. A key aspect of the architecture is the concept of network layers. Typically, networks are managed on a per-layer basis, and interactions between the layers follow client/server relationships. For telecom applications, OAM is defined on a per-layer basis.

For a modelling construct such as [ITU-T G.805], a key aspect of the model is that there are well-defined interactions between functions. Common constructs in [ITU-T G.805] models include trails (which support the end-to-end transfer of information and the various adaptation, termination and connection functions). The newer ITU-T models to define packet networks describe "flows". The work in [ITU-T G.8264] had anticipated this and thus it described timing flows.

The major benefit of architectural modelling is that if properly specified and followed, functional interactions are fully understood from the network level and therefore a complete specification of equipment consistent with the capabilities of the network is possible. Additionally, this results in a network that has a high level of interoperability and is fully manageable.

The model to support time/phase

Extension of the [ITU-T G.8264] models to cover time/phase becomes conceptually straightforward and is shown in Figure A.1. Here the output of the adaptation function is time/phase. The format of time/phase is not considered at this point. The important aspects are that the input to the source adaptation function must have additional information (time/phase), rather than simply a frequency reference. The information that is carried across the network remains, from the network perspective, the same as in the frequency only case. The network carries PTP packets. The adaptation functions would be responsible for producing the appropriate outputs. This only shows the timing path and traverses multiple packet network elements. This is illustrative of the model only.

In the case where frequency output is also required, this could be via the adaptation function. For simplicity, this is not shown in the figure, but it could be described (i.e., and additional frequency output could be provided).

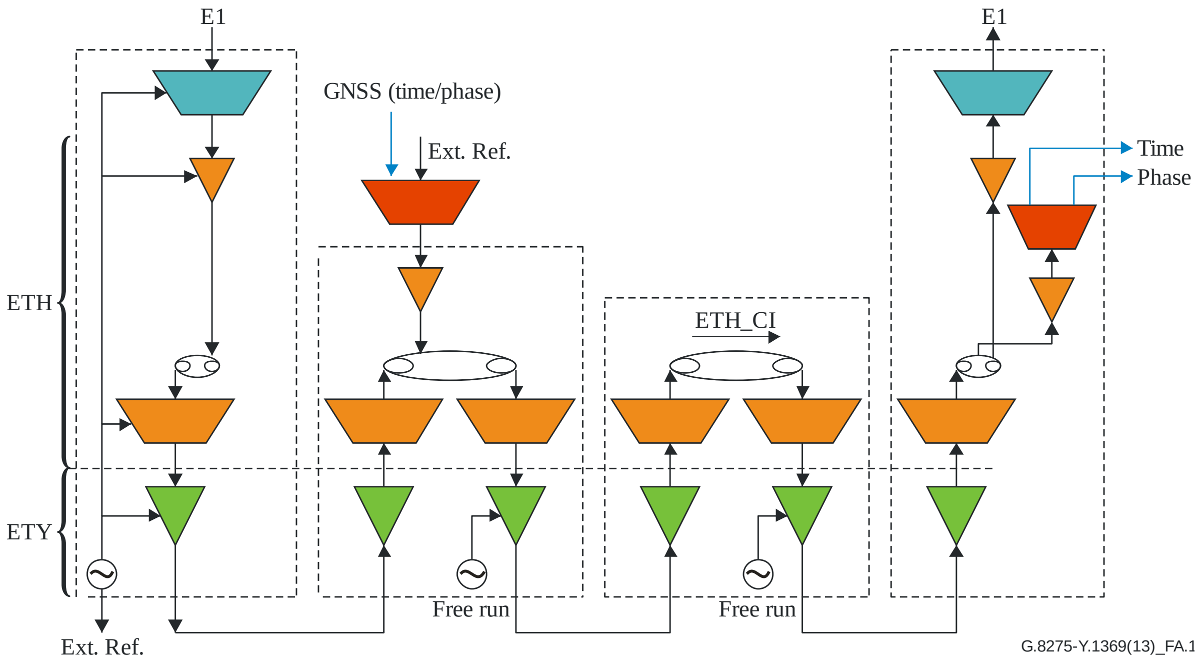


Figure A.1 – Extension of basic [ITU-T G.8264] model to support time/phase

Packet time/phase with frequency support by the network

Figure A.2 shows how time/phase can be assisted with frequency. In this specific example, the frequency reference is provided via synchronous Ethernet. A similar model could be developed where the input is via an external interface. This model begins to illustrate the independence of time/phase with frequency.

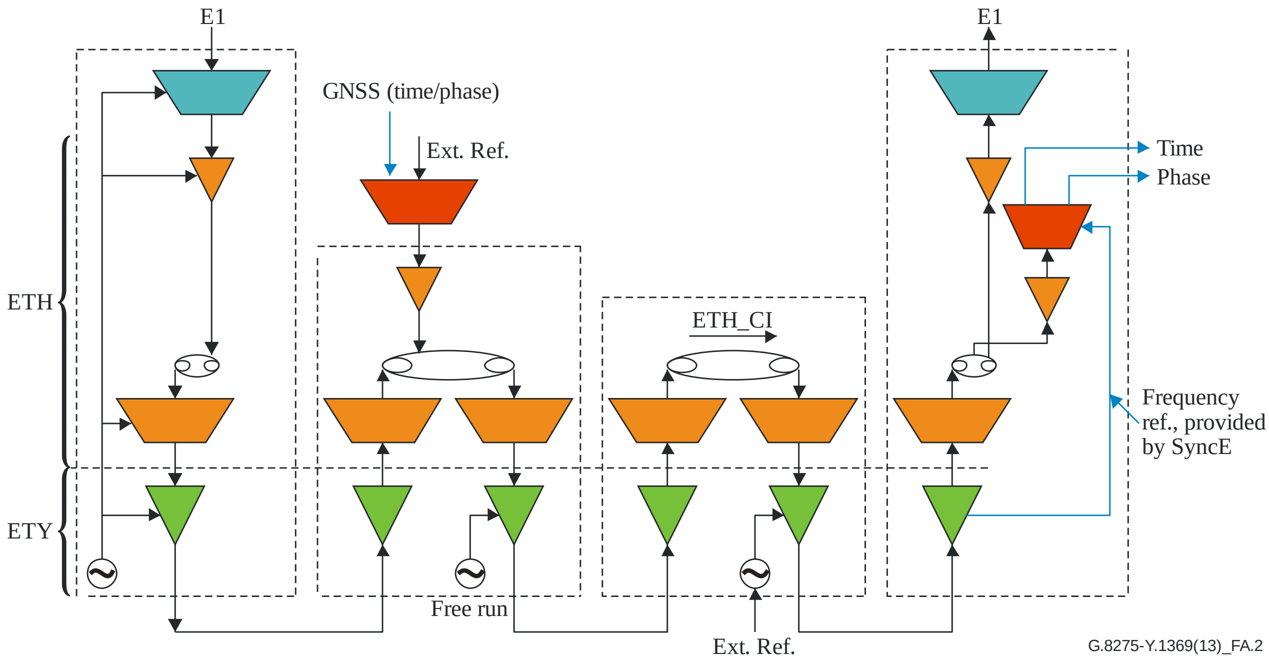


Figure A.2 – Time/phase with frequency support provided by the network (e.g., synchronous Ethernet)

Annex B

Inclusion of a virtual PTP port on a PTP clock

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

This annex describes the model for inclusion of a unidirectional, phase/time interface on a PTP clock. High-level principles are introduced in this annex.

This interface will be referred to as a virtual PTP port. This virtual PTP port may be used to model:

- An external input signal of the clock (e.g., coming from a PRTC, such as 1PPS+ToD).
- An external output signal of the clock (e.g., going to an end application, such as 1PPS+ToD).
- An internal input (i.e., an input that originates within the node and is not accessible externally) to a PTP clock that is coming from a source outside of the PTP clock's domain.
- An internal output (i.e., an output that originates within the node and is not accessible externally) of a PTP clock that is going to a sink outside of the PTP clock's domain.

When associated with an external input signal, a virtual PTP port allows this external interface to participate in the PTP protocol. As an input, this external port can participate in the source selection with an associated virtual E_{rbest} using the associated virtual PTP port.

When associated with an external output signal, a virtual PTP port allows communication of the PTP clock information to other equipment.

Not all parameters supported by the virtual PTP port are required to be supported by the PTP clock. The parameters grouped as locally set are not transmitted across the virtual PTP port but are set internally by the receiver of the virtual PTP port information. The parameters supported by a virtual PTP port are listed below.

– Time properties data set
  - Leap61
  - Leap59
  - currentUtcOffsetValid
  - ptpTimescale
  - timeTraceable
  - frequencyTraceable
  - timeSource
  - currentUtcOffset
– Parent data set
  - grandmasterIdentity
  - grandmasterClockQuality
    - clockClass
    - clockAccuracy
    - offsetScaledLogVariance
  - grandmasterPriority1
  - grandmasterPriority2

– Other parameters
  - stepsRemoved
  - versionPTP
  - domainNumber
  - Time of day
– Locally set
  - Signal fail (SF)
  - localPriority
  - portNumber

NOTE 1 – The stepsRemoved attribute must be set to zero in the case where a PRTC is connected to an external input signal of the node.

NOTE 2 – The SF is a local property of the PTP clock. Signal fail is set to TRUE when the PTP clock determines the input virtual PTP port (e.g., 1PPS, GNSS) is not useable. When SF is TRUE the portDS.SF parameter is set to TRUE.

NOTE 3 – When the external input virtual PTP port is a local external physical clock source, such as GNSS, the grandmasterIdentity assigned to the input virtual PTP port is the clockIdentity of the PTP clock itself.

NOTE 4 – The portNumber assigned to the virtual PTP port is set to a value different from the portNumber values already assigned to the other PTP ports of the PTP clock.

Annex C

Options to establish the PTP topology with the alternate BMCA

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

For the ITU-T PTP telecom profiles [ITU-T G.8275.1] and [ITU-T G.8275.2] that include a localPriority attribute, the alternate best master clock algorithm (BMCA) of those profiles allows two main approaches to set up the topology of the phase/time synchronization network:

– <u>Automatic topology establishment</u>: When configuring the localPriority attributes 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 the shortest paths to the T-GMs is built after this operation. In this mode, during failure events and topology reconfiguration, the alternate BMCA will be run again and result in a new synchronization tree. This alternate BMCA operation ensures that no timing loop will be created without requiring manual intervention or prior analysis of the network. The convergence time to the new PTP topology depends on the size of the network, and on the specific configuration of the PTP parameters.

– <u>Manual network planning</u>: The use of the localPriority attributes 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 D

Synchronization uncertain indication (optional)

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

This annex is used in the ITU-T PTP telecom profiles [ITU-T G.8275.1] and [ITU-T G.8275.2]. It is optional, but if implemented, it is necessary for the equipment to conform to the requirements contained herein. When a PTP clock selects a new parent as a synchronization time source, the PTP port associated with that new parent is placed in the UNCALIBRATED state. This PTP port state indicates that the PTP clock is in the process of synchronizing to the time source. The duration and functionality of this state is implementation specific. During this period, the PTP clock may have large or fast changes in frequency and phase, and while it is desirable that the updated parent information be propagated downstream to allow the topology to settle, it may not be desirable for the downstream PTP clocks to use the timing information. Therefore, communicating to downstream PTP clocks about the UNCALIBRATED state would be beneficial.

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

- the synchronizationUncertain flag of the Announce message received from the parent clock is TRUE; or
- the ingress port is in the UNCALIBRATED state; or
- implementation specific criteria.

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

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

Appendix I

Architecture for time and phase distribution over a packet network providing PTS at the protocol level

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

This appendix describes an alternative to the architecture for time and phase distribution using FTS described in this Recommendation, where not every network element is required to provide timing support. It will operate over a unicast IP network, in a similar manner to the existing frequency distribution architecture, but adapted to carry time and phase, as well as frequency. The architecture and its associated PTP profile are still under development and the accuracy and stability of time and phase distribution using this architecture is not yet known.

This future architecture is expected to address use cases where the operator wants to distribute accurate time and phase over an existing network and cannot upgrade the network to provide timing support in every network node. Additionally, a portion of the network may be provided by a third party and outside the administrative scope of the primary operator. The performance aspects and impacts of these use cases are still under study.

This appendix presents the initial concepts.

I.1 Architecture for PTS

The following four architectural aspects are covered in this appendix:

1) general packet-based timing distribution architecture;
2) timing protection aspects and functions;
3) partitioning across multiple administrative domains;
4) use of multiple underlying technologies.

I.1.1 Timing distribution architecture

[ITU-T G.8265] describes an architecture for frequency distribution using packet timing protocols. In this architecture, a frequency reference is connected to a packet master clock and distributed to the packet slave clocks using packet timing signals. The packet network itself is "timing unaware", i.e., it does not contain any elements that provide assistance or correction to the packet timing signals.

The same method can be considered and adapted to distribute time and phase to the packet slave clocks. This requires changing the frequency reference to a time reference derived from a PRTC (PRTC, normally a GNSS receiver referencing time back to UTC). It also requires the timing protocol to operate in two-way mode, i.e., to send event messages in both directions. If the PTP protocol is used, this means using both *sync* and *delay_request* messages.

The applications requiring accurate time and phase distribution described in [ITU-T G.8271] place a much more stringent requirement on the network and packet slave clock performance than for frequency distribution. The objective is to address some of the classes described in [ITU-T G.8271]. To achieve this, it may be required to reduce the number and type of network elements that can be traversed compared to [ITU-T G.8265.1]/[ITU-T G.8261.1] while still meeting the performance requirements.

There are two main ways to accommodate this reduction:

1) use boundary clocks to break the network up into smaller segments (boundary clocks recover and filter the timing from the original packet timing signal and generate a new packet timing signal to forward the timing downstream);

2 move the PRTC and packet master clock closer to the packet slave clock (i.e., a more distributed architecture).

These approaches are shown in Figure I.1:

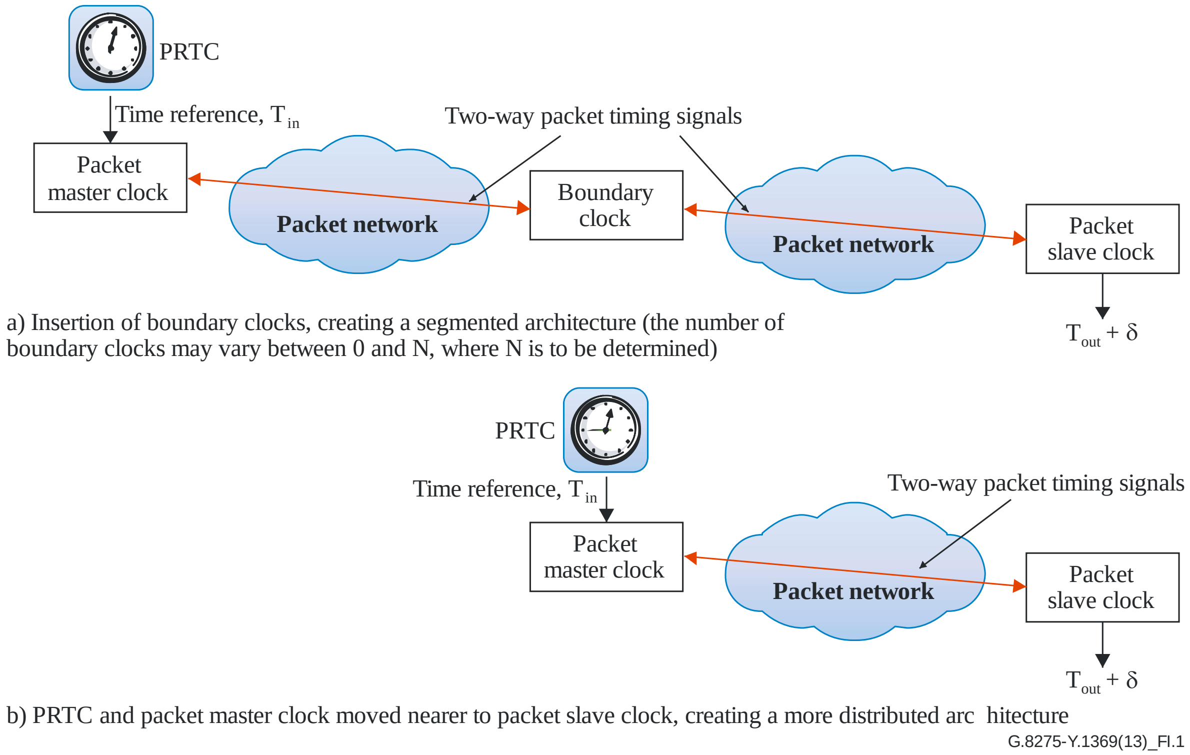


Figure I.1 – Modified architecture to support time and phase distribution

In both cases, the stability and performance of the boundary clocks and packet slave clocks may be enhanced by provision of a stable physical layer frequency reference, such as synchronous Ethernet, if available, as shown in Figure I.2:

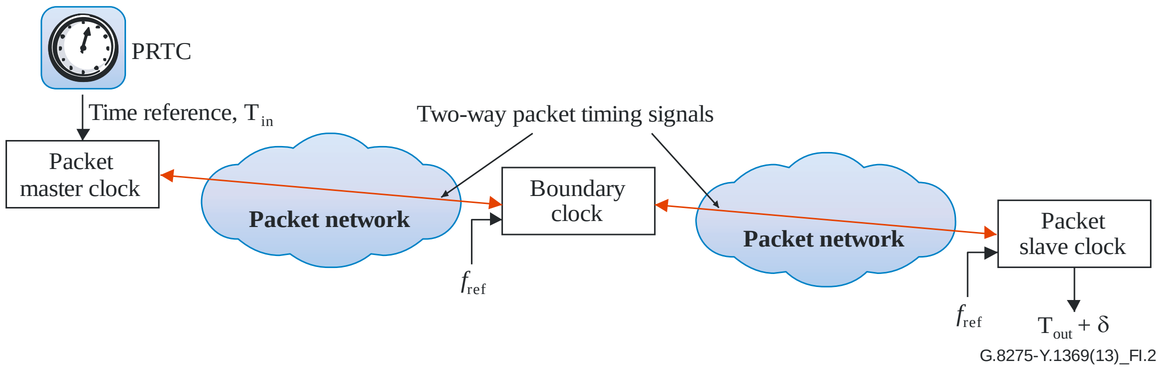


Figure I.2 – Use of physical layer frequency reference (if available)

The specification of the boundary clock in Figure I.2 is not identical to the boundary clock for FTS. Similarly, the specification of the packet slave clock in Figure I.2 is not the same as the packet slave clock for FTS or the packet slave clock for frequency described in [ITU-T G.8263].

Performance specifications for the clocks described in this appendix are for further study.

I.1.2 Timing protection aspects

One method of providing protection in case of network failure is to provide access to an alternative packet master clock or boundary clock. The details of the master selection mechanism are under study.

A second method of protection is based on the use of a frequency reference (if available) to maintain the time base of the various clocks. For example, [ITU-T G.8272] describes the use of a frequency reference (such as synchronous Ethernet) to maintain the PRTC output during periods when the GNSS signal is unavailable.

This method can be applied to both the boundary clock and the packet slave clock. A physical layer frequency reference, if available, can be used to maintain the time output of the boundary clock and/or packet slave clock during periods when the packet timing signal is either unavailable or unusable. This is shown in Figure I.3:

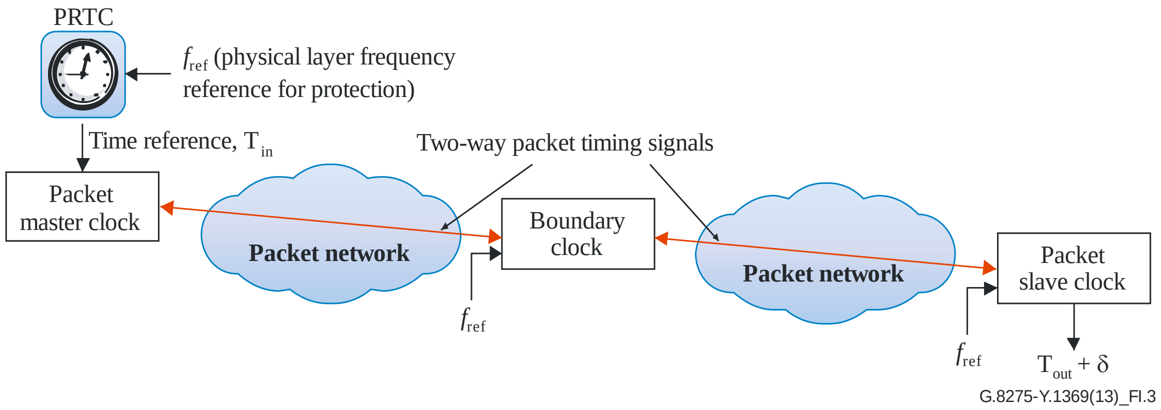


Figure I.3 – Protection using physical layer frequency references

I.1.3 Partitioning across multiple administrative domains

In some cases, operators purchase services from other operators in order to provide access to remote equipment or networks. The use of the PTS architecture permits the distribution of time and phase across such alternative access vendors, even where such vendors may not provide timing support, although the performance of such timing distribution schemes may be undefined.

For example, Figure I.4 shows an example of such an alternative access provision. In this example, a boundary clock is used to ensure a clean hand-off point to the second network operator.

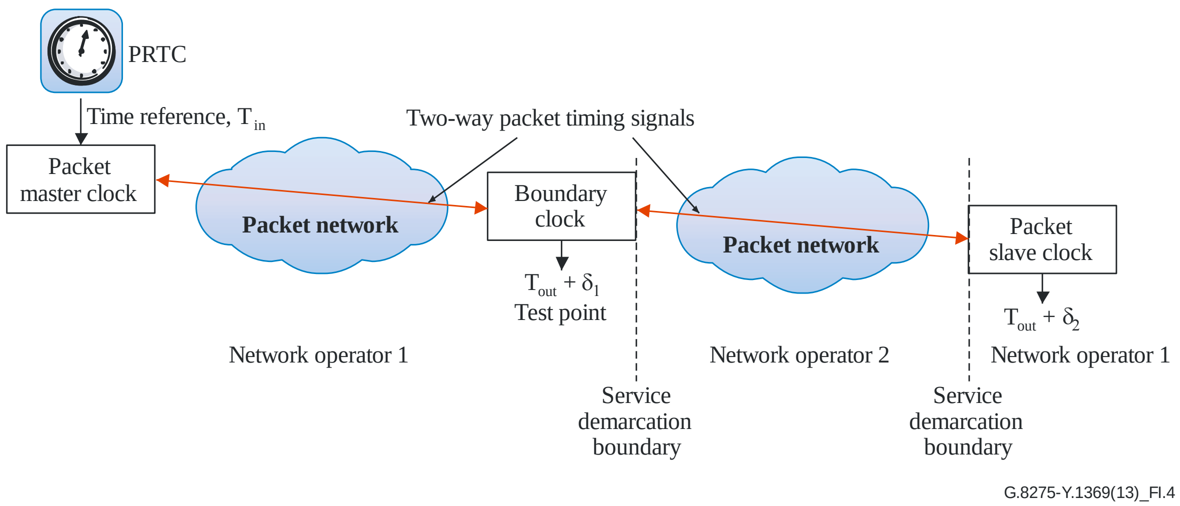


Figure I.4 – Timing transmission over a second operator's network

Passing accurate phase/time between administrative domains is for further study. Issues surrounding the demarcation of the packet timing flow and the transferred performance between operators may exist. It may be difficult to determine the location of performance problems especially if the packet timing is passing through multiple administrative domains.

When multiple administrative domains are involved, other methods may be required to deliver accurate phase/time reference to the mobile network operator. For instance, a carrier operator may provide a phase/time reference as a service. The details of these other methods are for further study.

I.1.4 Use of multiple underlying technologies

Packet networks are built on a number of different underlying technologies. Some technologies not only create PDV, but also introduce significant asymmetry or difference in delay between the forward and reverse paths. If uncorrected, this asymmetry will cause an error in the packet slave clock's estimate of the correct time or phase.

Where such technologies are used, it will be necessary to verify that they are suitable for accurate time and phase transfer, or that appropriate timing support has been built into the equipment. Details of the PDV and asymmetry contributions of individual transport technologies and their suitability for accurate time and phase distribution are for further study.

Appendix II

An example of PRTC switching by the BMCA in a ring network

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

Figure II.1 and Figure II.2 show the normal and abnormal application scenarios. In the figures, the working PRTC has higher priority than the backup PRTC.

Normally, the working PRTC (i.e., PRTC-1) sends frequency via a 2048 kHz or 2048 kbit/s signal and phase/time via a 1PPS + ToD signal to the T-BC that it is connected to. This T-BC is the GM, and all the network elements including the T-BC connected to the backup PRTC (i.e., PRTC-2) track the phase/time of the working PRTC, as shown in Figure II.1.

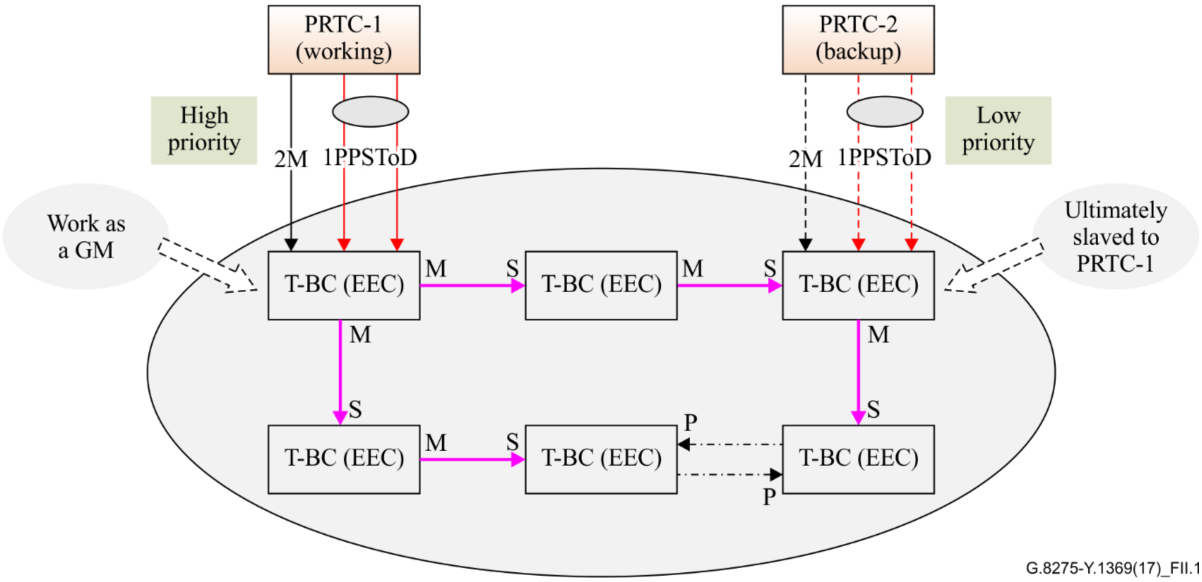


Figure II.1 − Normal state (T-BC connected to working PRTC is working as a GM)

If, at some time, PRTC-1 is degraded (e.g., the GNSS signal is lost), or the connection between PRTC-1 and the T-BC it is connected to fails, PRTC-2 becomes the working PRTC. All the network elements will then track the phase/time of PRTC-2, and the T-BC initially connected to PRTC-1 will no longer be the GM, as shown in Figure II.2.

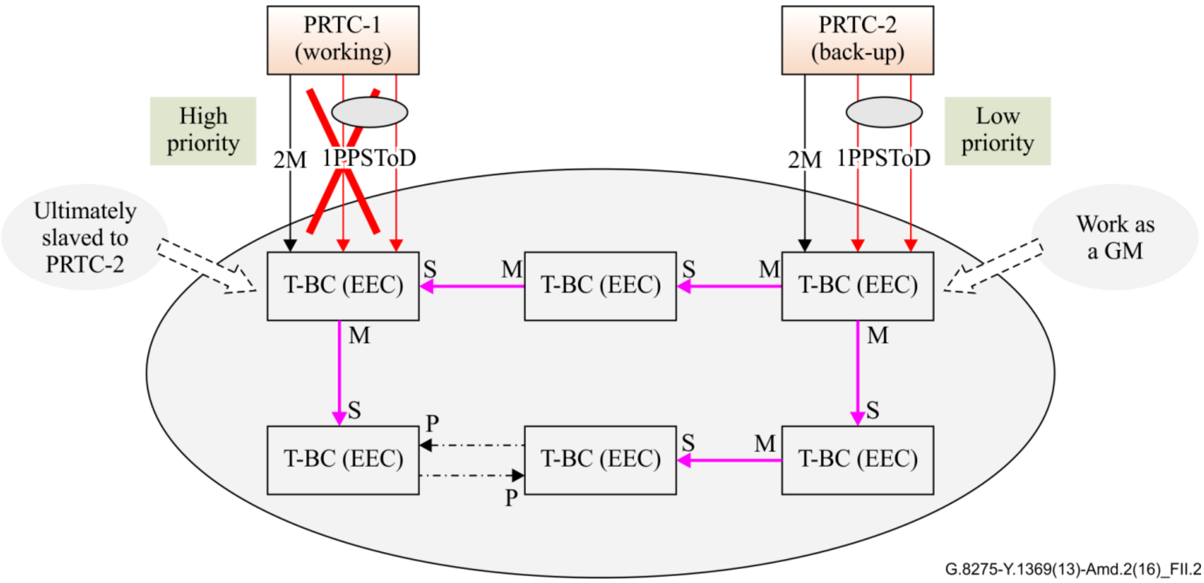


Figure II.2 – Abnormal state (the working PRTC has failed)

The above operation can be obtained using the BMCA by setting the clockClass of PRTC-1 and PRTC-2 to 6 when they are operating normally (i.e., when they are traceable to a GNSS) and setting priority2 for PRTC-1 to be better (i.e., to have a smaller value) than priority2 for PRTC-1. Both PRTC-1 and PRTC-2 are attached to the respective T-BCs via virtual PTP ports (see [ITU-T G.8275.1]), and the respective PTP attributes, which include clockClass and priority2 are transferred via the 1PPS+ToD interfaces to the virtual PTP ports (see [ITU-T G.8271]). With these values for clockClass and priority2 (and with clockAccuracy and offsetScaledLogVariance of PRTC-1 and PRTC-2 the same) PRTC-1 will win the BMCA when it is operating normally because its clockClass will be the same or better than the clockClass of PRTC-2 and its priority2 will be better than priority2 of PRTC-2. If PRTC-1 degrades, its clockClass will be worse than that of PRTC-2 and PRTC-2 will win the BMCA. If PRTC-1 is lost (i.e., the connection from PRTC-1 to the T-BC it is attached to is cut), there will be no input to the virtual PTP port and PRTC-2 will win the BMCA.

Appendix III

Generic IWF node

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

III.1 Introduction

In some deployment scenarios an inter-working function (IWF) may be used to connect synchronization network segments that are running different PTP profiles. An example is shown below in Figure III.1 where an IWF, containing a clock among other functions, would be needed to translate from the FTS profile ([ITU-T G.8275.1]) to the PTS ([ITU-T G.8275.2]) going downstream from the T-GM towards the end application. In this case, the IWF may be denoted as IWF F-P to indicate the direction of profile translation full to partial. Similarly, IWF P-F indicates the direction of profile translation partial to full.

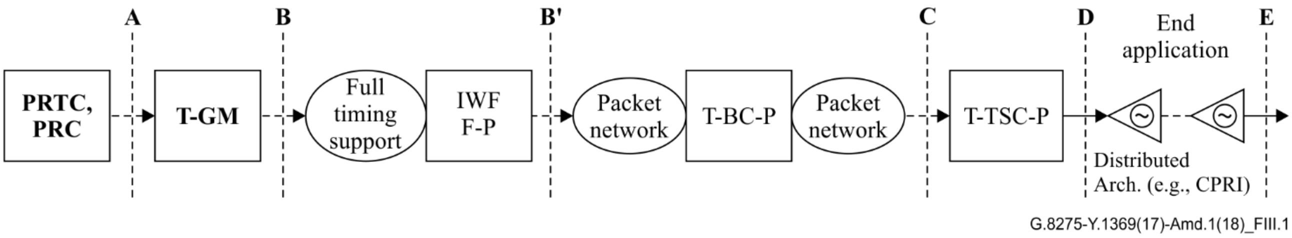


Figure III.1 – Deployment case requiring IWF

A model for the IWF is shown in Figure III.2. This IWF uses a virtual PTP port to inter-connect PTP clocks from different PTP profiles. The IWF consists of several aspects.

– PTP clock, running profile A
  - several PTP ports
  - output virtual PTP port
– PTP clock, running profile B
  - several PTP ports
  - input virtual PTP port
– Profile translator

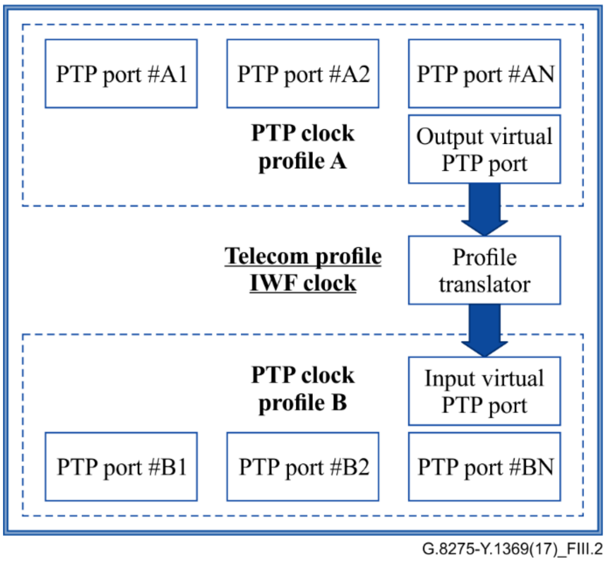


Figure III.2 – Model of telecom profile IWF clock

A typical scenario would have a uni-directional timing service flowing from one profile (profile A) to the other profile (profile B). The performance of such a clock may be defined in a Recommendation, and may be built as a slave clock of profile A and a master clock of profile B. Continuing the description of the typical scenario, the PTP clock configured with profile A would operate as a slave-only clock, while the PTP clock configured with profile B would operate as a master clock with masterOnly PTP ports. The PTP clock configured with profile A would comply to all the requirements defined for profile A and the PTP clock configured with profile B would comply to all the requirements defined for profile B.

For IWF F-P and P-F, the clock performance limits mainly consider the type of network used on the slave port, regardless of the one used on the master port.

– For a synchronization interworking function IWF F-P translating from the FTS profile ([ITU-T G.8275.1]) to the PTS profile ([ITU-T G.8275.2]), the performance limits may be the same as those for a T-BC in [b-ITU-T G.8273.2].
– For a synchronization interworking function IWF P-F translating from the PTS profile ([ITU-T G.8275.2]) to the FTS profile ([ITU-T G.8275.1]), the performance limits may be the same as those for a T-BC-A or T-BC-P in [b-ITU-T G.8273.4].

However, application-specific implementations with different limits are also allowed. It is the responsibility of the operator to choose the appropriate type of IWF based on the network configuration.

III.2 Inter-working between the [ITU-T G.8275.1] and [ITU-T G.8275.2] profiles

The interworking function translating between the [ITU-T G.8275.1] and [ITU-T G.8275.2] profiles is simplified due to the many common aspects shared between these two profiles. Table III.1 outlines areas of commonality as well as differences between the two profiles.

Table III.1 – Common aspects and differences between the [ITU-T G.8275.1] and [ITU-T G.8275.2] profiles

Functionality	[ITU-T G.8275.1]	[ITU-T G.8275.2]
Network support	FTS from network	PTS from network
Transport layer	Layer 2 (IEEE1588-2008 Annex F, OTN)	Layer 3 (IEEE1588-2008 Annex D and E)
Domain	24 – 43	44 – 63
Clock types (BC)	T-BC (slaved to another PTP clock, or can become T-GM)	T-BC-P, T-BC-A
Message rates	Fixed rates • Sync: 16 pkts/s • Delay_req: 16 pkts/s • Announce: 8 pkts/s • Signalling FFS • Management FFS	Negotiated rates • Sync: 1 – 128 pkts/s • Delay_req: 1 – 128 pkts/s • Announce: 1 – 8 pkts/s • Signalling: used for unicast rate negotiation • Management FFS
Network architecture	Use-cases and architecture per [ITU-T G.8275]	
BMCA	Common (same) ABMCA	
Fields ignored (common behaviour)	controlField, priority1, PTP profile specific 1,2 = FALSE, Reserved = FALSE	
Fields ignored (different behaviour)	unicastFlag	
Fields used (common behaviour)	• ptpTimescale must be TRUE (not ignored, it must actually be true) • twoStepFlag, leap61, leap59, currentUtcOffsetValid same definition as IEEE1588-2008 • timeTraceable, frequencyTraceable	
Fields used (different behaviour)	unicastFlag must be FALSE	unicastFlag must be TRUE
Asymmetry control		Static asymmetry controlled using assisted PTS
Physical layer	Physical layer frequency support using SyncE/E1/T1	Physical layer frequency support is optional
Unicast negotiation support	No (not allowed)	Yes (allowed – must be supported)
VLAN allowed	No	Yes

When the PTP profiles are part of an IWF, they may be modelled as inter-connected using a virtual PTP port that is described in Annex B. Table III.2 provides information on how to set or convert those parameters. This table does not define that these must be the values used on the internal virtual PTP port inside the equipment. Table III.2 covers only translation where there is an active selected input that is from the 'PTP clock profile A'. This table does not apply when the 'PTP clock profile B' is in holdover.

Table III.2 –Translation between the [ITU-T G.8275.1] and the [ITU-T G.8275.2] profiles

Group	Field	In Profile A: [ITU-T G.8275.1] Out Profile B: [ITU-T G.8275.2]	In Profile A: [ITU-T G.8275.2] Out Profile B: [ITU-T G.8275.1]
Time properties DS	Leap61	Direct mapping	Direct mapping
Time properties DS	Leap59	Direct mapping	Direct mapping
Time properties DS	currentUtcOffsetValid	Direct mapping	Direct mapping
Time properties DS	ptpTimescale	No translation; set TRUE	No translation; set TRUE
Time properties DS	timeTraceable	Direct mapping	Direct mapping
Time properties DS	frequencyTraceable	Direct mapping	Direct mapping
Time properties DS	timeSource	Direct mapping	Direct mapping
Time properties DS	currentUtcOffset	Direct mapping	Direct mapping
Parent DS	gmIdentity	See Annex B, Note 3	See Annex B, Note 3
Parent DS	gmClockQuality::clockClass	Direct mapping	Direct mapping
Parent DS	gmClockQuality::clockAccuracy	Direct mapping	For further study
Parent DS	gmClockQuality::offsetScaledLogVariance	Direct mapping	For further study
Parent DS	grandmasterPriority1	Direct mapping	Direct mapping
Parent DS	grandmasterPriority2	Direct mapping	Direct mapping
Other	stepsRemoved	For further study	For further study
Other	versionPTP	No translation; set by 'Profile B'	No translation; set by 'Profile B'
Other	domainNumber	No translation; set by 'Profile B'	No translation; set by 'Profile B'
Other	Time of day	From 'Profile A' clock	From 'Profile A' clock
Local	Signal Fail (SF)	See Annex B, Note 2	See Annex B, Note 2
Local	localPriority	No translation, set by 'Profile B'	No translation, set by 'Profile B'
Local	portNumber	See Annex B, Note 4	See Annex B, Note 4

III.3 Generation of the physical layer frequency signal by the IWF

A synchronization IWF F-P node has an input PTP reference timing signal carried over an FTS synchronization network that includes a mandatory physical layer frequency signal (e.g., SyncE, SDH, …), and delivers a PTP reference timing signal carried over a PTS synchronization network.

NOTE 1 – The physical layer frequency signal generation is optional on the PTS port(s). If used, it is specified by the physical layer-based frequency synchronization requirements ([b-ITU-T G.812], [ITU-T G.8262], [ITU-T G.8262.1] for frequency and time error, [b-ITU-T G.781] and [ITU-T G.8264] for SSM QL-TLV).

A synchronization IWF P-F node has an input PTP reference timing signal carried over a PTS synchronization network that includes an optional physical layer frequency signal (e.g., SyncE, SDH, …), and delivers a PTP reference timing signal carried over an FTS synchronization network.

NOTE 2 – The physical layer frequency signal generation is mandatory on the FTS port(s). If a valid physical layer frequency signal is delivered by the upstream PTS network and if the synchronization IWF P-F node supports the distribution of such a signal, then this distribution is specified by the physical layer-based frequency synchronization requirements ([b-ITU-T G.812], [ITU-T G.8262], [ITU-T G.8262.1] for frequency and time error, [b-ITU-T G.781] and [ITU-T G.8264] for SSM QL-TLV). Otherwise, the quality level to be used on the physical layer frequency signal shall be generated following the rules defined in Annex F of [ITU-T G.8275.2].

Appendix IV

Use cases for mapping from PTP clockClass values to quality levels

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

This appendix provides use cases for mapping from PTP clockClass values to quality levels (QLs) for use by synchronization status message (SSM) and Ethernet synchronization messaging channel (ESMC) when using PTP time profile for frequency recovery.

IV.1 Use case I

Due to the evolution from 3G to 4G, base stations of different generations coexist. In some situations, two different base stations, such as where a wideband code division multiple access (WCDMA) station and a long term evolution (LTE) station are connected to the same node. As shown in Figure IV.1, a WCDMA station and an LTE station are connected to the same [ITU-G.8275.2] T-TSC-P/ T-TSC-A node. The WCDMA station requires a frequency signal from the T-TSC-P/ T-TSC-A node. However, in the scenario of partial-PTP timing support, the node can only get PTP messages through the middle network that does not support PTP and SyncE functions. Therefore, to provide a frequency signal to the WCDMA station, the T-TSC-P/ T-TSC-A node has to transform the PTP clockClass values into QLs. In this case, the mapping from PTP clockClass values to QLs is required.

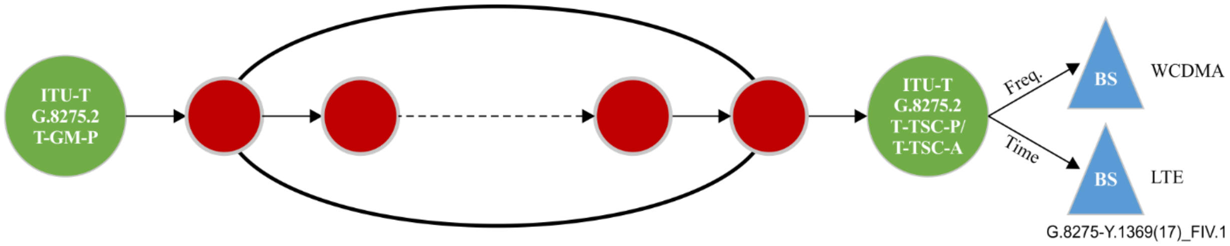


Figure IV.1 – Use case I

IV.2 Use case II

To provide frequency and time service to a local network area (e.g., to deploy the small cells in a building) and meet the stringent accuracy requirement, one possible convenient solution is to deploy a boundary clock with GNSS input close to an access network area rather than rely on the grandmaster (GM) in the core network.

This type of boundary clock with GNSS input usually supports at least two types of input sources: GNSS or PTP input from the upstream network. The boundary clock with GNSS input also provides the PTP output and frequency output (e.g., SyncE or 2048 kHz/2048 kbit/s) simultaneously, to support various applications.

When the boundary clock with GNSS input chooses the PTP input and provides the frequency output, it should support transforming the PTP clockClass values into QLs. For example, in Figure IV.2, the boundary clock with GNSS input is deployed close to small cells and provides services for users within a certain area. The boundary clock with GNSS input may get time source via a full- or partial-PTP path. At the same time, the boundary clock with GNSS input offers time and frequency services to small cells. To provide frequency service for small cells, the mapping from PTP clockClass values to QLs is also required for the boundary clock with GNSS input.

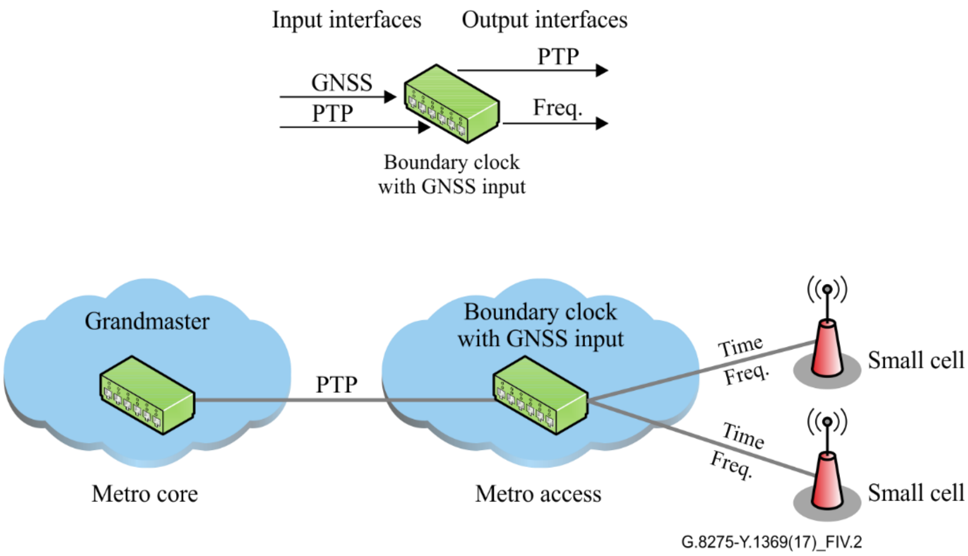


Figure IV.2 –Use case II

Appendix V

Deployment examples and the use of partially aware clock types

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

This Recommendation includes several partially aware clock types: T-TSC-A, T-TSC-P, T-BC-A and T-BC-P. Figure V.1 illustrates the potential use of these clocks in example network deployments. The examples included in the figure are not meant to be exhaustive of all possible network deployments, but shows a few simple examples that provide clarity between the partially aware clock types.

– Example 1 shows a T-GM with a direct PTP connection to a T-TSC-P, without any intermediate T-BC-P or T-BC-A.
– Example 2 shows a T-GM with a direct PTP connection to a T-TSC-A that has local time reference (LTR) support for asymmetry compensation, without any intermediate T-BC-P or T-BC-A.
– Example 3 shows a T-GM with a PTP connection to a T-BC-P, which in turn has a PTP connection to a T-TSC-P.
– Example 4 shows a T-GM with a PTP connection to a T-BC-P, which in turn has a PTP connection to a T-TSC-A. The T-TSC-A has local time reference support for asymmetry compensation.
– Example 5 shows a T-GM with a PTP connection to a T-BC-A, which in turn has a PTP connection to a T-TSC-P. The T-BC-A has local time reference support for asymmetry compensation.
– Example 6 shows a T-GM with a PTP connection to a T-BC-A, which in turn has a PTP connection to a T-TSC-A. The T-TSC-A has local time reference support for asymmetry compensation.

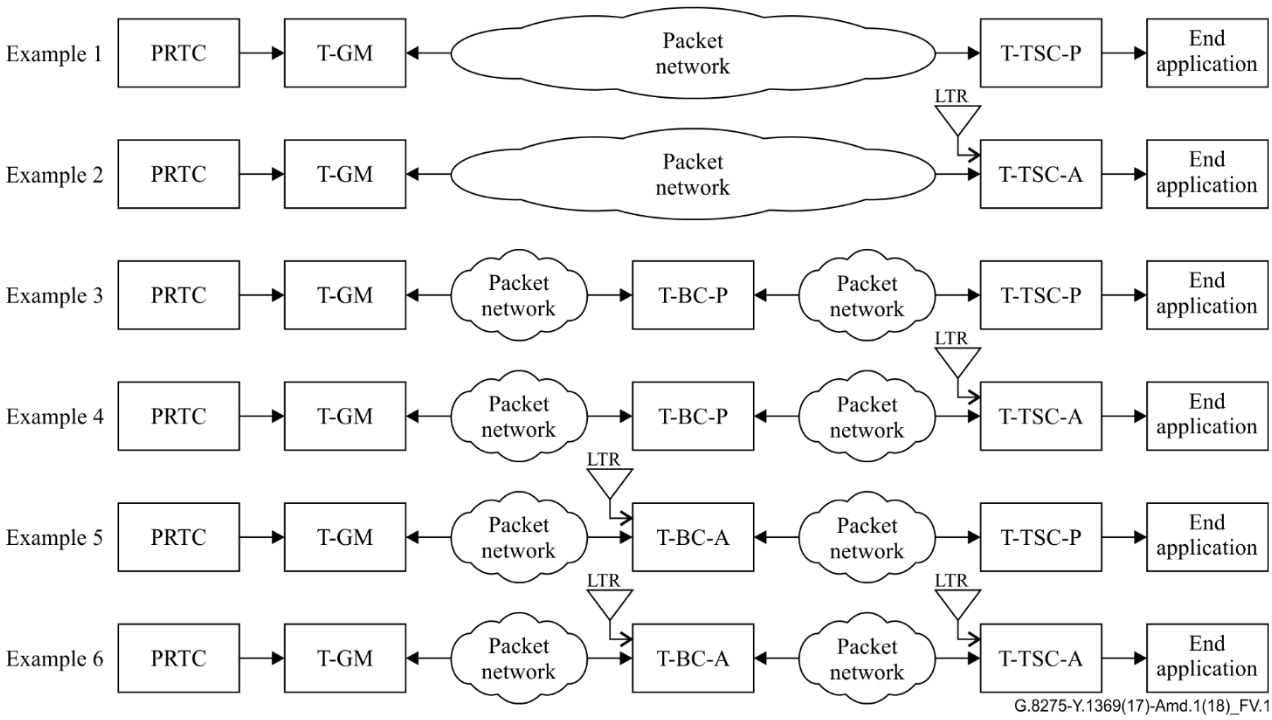


Figure V.1 – Scenarios showing T-BC-A and T-BC-P in PTS and APTS

NOTE 1 – The PRTC and the T-GM may be embedded in the same equipment.

NOTE 2 – The T-TSC-A or T-TSC-P and the End Application clock may be embedded in the same equipment.

NOTE 3 – The local time reference may be in a separate, co-located equipment, or embedded within the same equipment, as the T-BC-A or T-TSC-A.

NOTE 4 – The examples show no or one T-BC-P or T-BC-A between the T-GM and the T-TSC-P or T-TSC-A; other numbers of T-BC-P or T-BC-A are possible.

Appendix VI

cnPRTC functional architecture

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

VI.1 Introduction

The coherent network PRTC connects primary reference clocks at the highest core or regional network level. This provides the ability to maintain network-wide ePRTC time accuracy, even during periods of regional or network-wide GNSS loss. Comparative measurements between the clocks is a central component of the cnPRTC system, thus monitoring of the clocks is also provided by the cnPRTC system.

VI.2 cnPRTC functional architecture

A central aspect to working with a group of clocks is the algorithm for combining them, which is known as a "timescale algorithm". These algorithms are important to national labs, GNSS control segments, and indeed to the establishment of UTC at the BIPM. Other aspects important to combining clocks in a network are also discussed below. Two examples of cnPTRC clock groups are shown in Figure VI.1, one with six clocks, which could be suitable to a central core, and another with three clocks, which could be suitable for a smaller regional area.

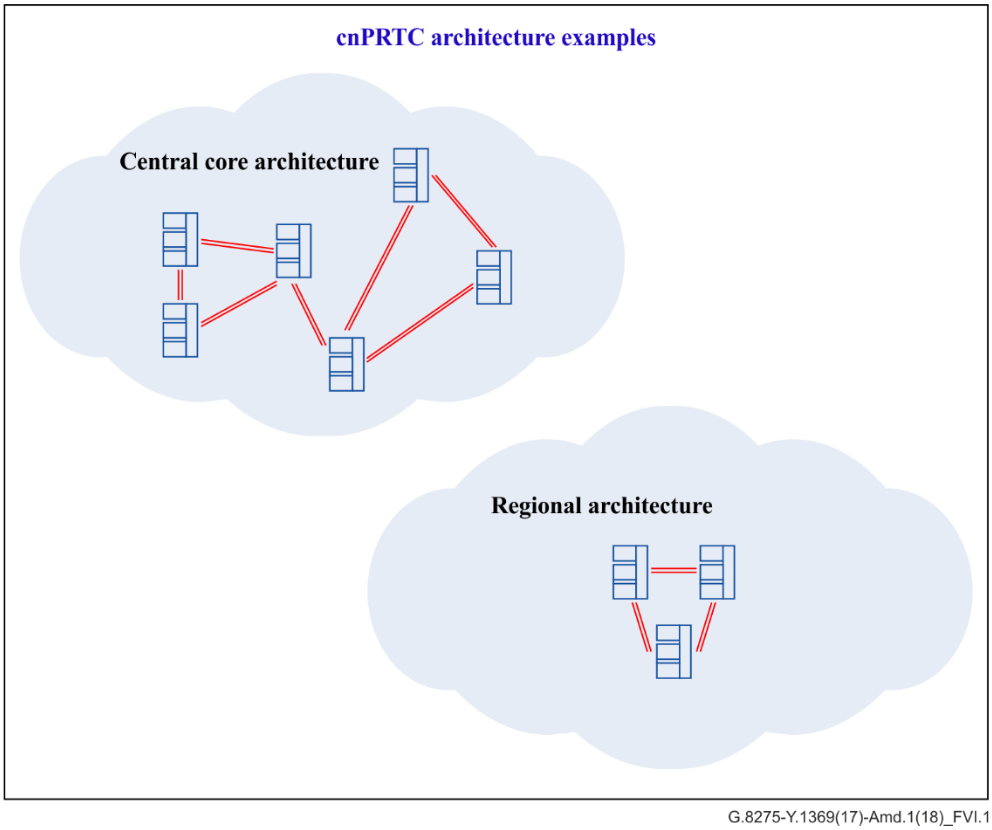


Figure VI.1 – Coherent network PRTC architecture examples

What distinguishes these examples from a standalone PRTC or ePRTC is the connection and interaction between the clocks. Note in the central core example, that the clocks are not completely meshed. Nevertheless, given the connections that are there, any clock can be compared to any other clock through a direct connection or indirectly through one or more intermediary connections.

References are made in this figure to common-view and all-in-view; further details are in [b-NIST] and [b-Weiss].

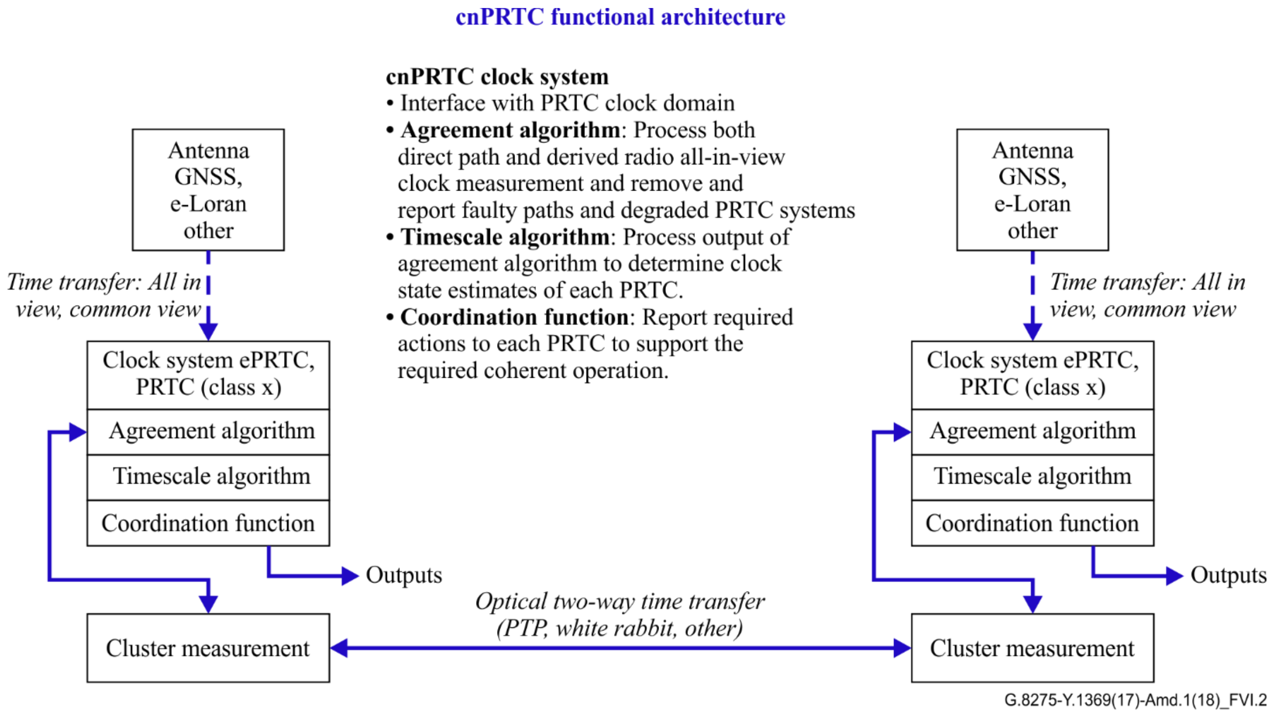


Figure VI.2 – Coherent network PRTC functional architecture

Figure VI.2 shows that there are three components to the ensembling function: (1) agreement algorithm, (2) timescale algorithm, and (3) coordination function. These are discussed below. As noted above, the "timescale algorithm" is at the heart of the ensembling function, though important aspects are also contained within the "agreement algorithm" and the "coordination function".

Agreement algorithm

The "agreement algorithm" provides a mechanism for weighting, de-weighting or potentially eliminating clocks. It is important to determine the group of clocks considered worthy of including in the coherency. The agreement algorithm refers to a methodology for networking clocks that has been in use for a number of decades. It is of critical importance in a real-world application of distributed networks with distributed timescales. A prominent example of this is the Network Time Protocol (NTP) intersection algorithm.

Timescale algorithm

The "timescale algorithm" is central to the ensembling function of the coherent network primary reference time clock, and more generally to the ensembling function of any group of clocks. If the "agreement algorithm" has established a valid group of clocks, then pairwise measurements can be used to evolve the timescale. An example of a "timescale algorithm" among the many in use in time and frequency metrology is the International Atomic Time (TAI) algorithm (see [b-Panfilo] for more details). A timescale algorithm looks at the pairwise measurements and determines the state estimates for the phase, the frequency and the drift, that need to be applied to any of those clocks to put it on the ensemble average.

Coordination function

The "coordination function" applies the corrections determined by the "timescale algorithm". It uses the knowledge gained from the timescale algorithm, the state estimates, and goes out to all the distributed clocks with instructions for actions to take. It is important to note that the result of the action taken, because of errors in the system, does not perfectly match the desired action. Without further action there would be a small accumulation of time error, with the clocks eventually drifting apart. Thus, continual measurements need also to be part of the coordination function, given that coherency is the goal. The coordination function includes two things –the instructions that are issued to the individual ePRTC or PRTC clocks to put them at the right time and the feedback to ensure that any errors are accounted for and corrected.

Summary: Agreement, timescale and coordination

In summary, three functions – the "agreement algorithm", the "timescale algorithm" and the "coordination function" – are combined for cnPRTC clock ensembling. The "timescale algorithm", which is at the heart of the combined function, looks at all the contributing members of the timescale grouping, determining what each of them needs to do. It is preceded by an "agreement algorithm", which validates the sources, and is followed by a "coordination function", which generates a coordinated timescale throughout a distributed set of systems.

The agreement algorithm, timescale algorithm and coordination function that are described above need to be implemented at each cnPRTC node, as indicated in Figure V1.2. The functional entity responsible is termed the cnPRTC clock combiner and is shown in Figure VI.3. In addition to the agreement algorithm, timescale algorithm and coordination function (described as the clock combiner function), additional functions are needed for measurement, fault detection and output. All combined, these functions form the cnPRTC clock combiner.

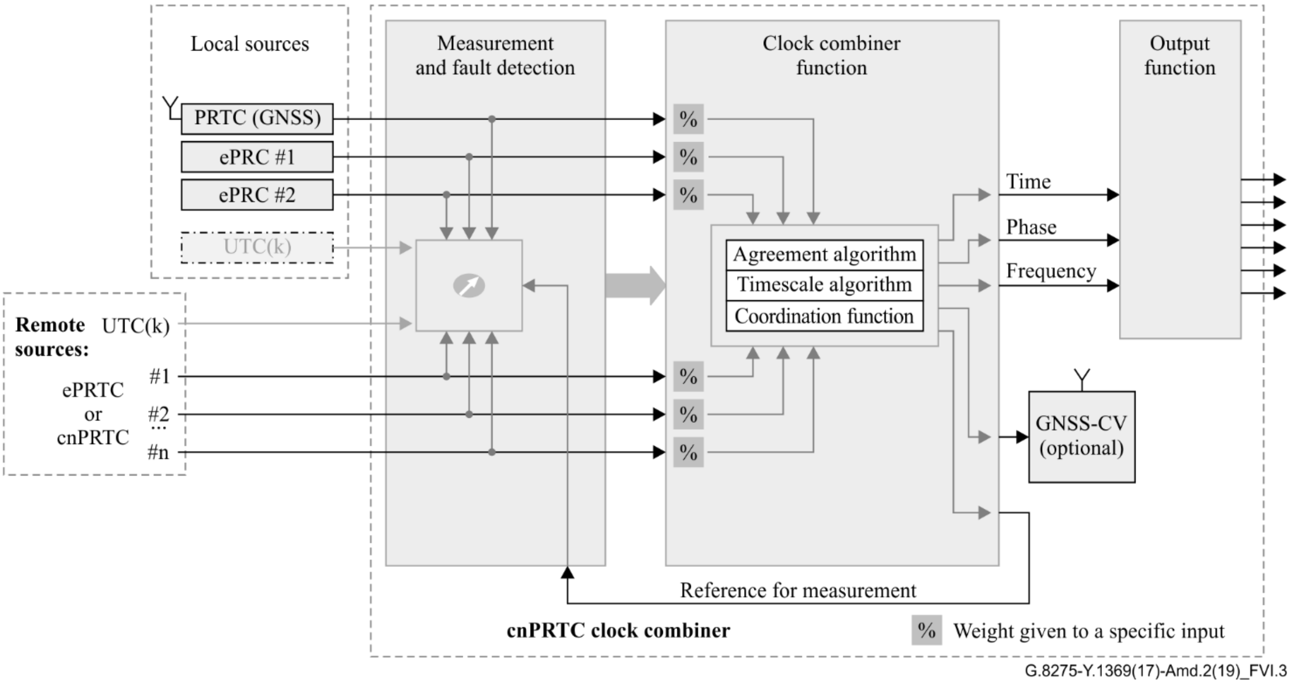


Figure VI.3 – Coherent network PRTC functional block diagram

NOTE 1 – The clock combiner needs not combine physical data, it could be based on measurement data only.

NOTE 2 – Depending on implementation, the cnPRTC function could be fully based on software (only). This functional block diagram shows the logical view.

NOTE 3 – Clock combiner algorithms are implementation specific.

NOTE 4 – Usage of UTC(k) is for further study.

Input sources can include both local and remote sources. Local sources can be PRTC (e.g., a GNSS receiver), atomic clock (e.g., ePRC) or a local UTC lab.

Remote sources are delivered via a high-accuracy time-transfer from neighbouring cnPRTC nodes or UTC(k) sources

The measurement and fault detection function are needed to compare and validate input sources against the output of the local clock combiner function. As indicated in Figure VI.3, this measurement and fault information is conveyed to the clock combiner function. The fault detection function identifies missing or corrupted signals. It does not consider the validity of information carried by the signals.

If the measurement and fault detection block determine that a signal is missing or corrupted, it sends that information to the clock combiner block, which is part of the information indicated by the thick grey arrow. However, the failed input signal is still input to the clock combiner block, and the clock combiner block uses the information it receives from the measurement and fault detection block to decide whether or not to include the signal.

The clock combiner function, with its agreement algorithm, timescale algorithm, and coordination function, makes use of the multiple available sources. A weighting function is applied to the individual inputs. For example, local sources may be given a higher weighting as compared to remote sources, or the weighting of a specific input may be adjusted or even squelched in the case of problems observed on the input.

A specific weight range is given to a specific input. The weight range of local sources is higher than remote sources by configuration. Due to specific measurement results, weight can be automatically adjusted within the configured range as determined by the agreement algorithm in the clock combiner function block. In case of problems, the specific input can be squelched based on the agreement algorithm. Except possibly for initialization, the weights are determined by the agreement algorithm.

The output function takes the time, frequency and phase output from the clock combiner function and generates the necessary signals for local (e.g., 10 MHz, 1PPS and ToD) and remote (e.g., PTP-FTS + SyncE) use. Multiple outputs of the same type may be required; principally for remote distribution. Outputs are for local usage, for example via a T-GM, or for providing a source for high-accuracy time transfer towards neighbour locations.

An additional optional output to provide input to GNSS CV (common view) is also shown. The results of these measurements can then be used for additional steering of individual cnPRTC clock combiner functions (e.g., as a remote input). GNSS CV measurement results may be used to compare a cnPRTC to other cnPRTCs. A BIPM like algorithm could optionally be used.

Remote sources are delivered via high-accuracy time transfer. This could be from neighbouring cnPRTC functions, or optionally, from a UTC(k) lab.

Appendix VII

cnPRTC deployment scenarios

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

For cnPRTC network deployment, the following scenarios are proposed for a step-by-step deployment approach. The scenarios can be regarded as network migration guidelines. The network specific deployment depends on many factors, like specific network architecture, availability of time transfer links, network size, etc. Therefore, using the specific scenarios for a specific network is up to the network operator.

Scenario 1:

- As basis: To deploy stand-alone ePRTC functions according to [b-ITU-T G.8272.1].
- This scenario would allow a network operator to start with several ePRTC functions according to [b-ITU-T G.8272.1] at centralized locations. Connecting time transfer links are not needed.

Scenario 2:

- To mesh neighborhood cnPRTC location with time transfer links.
- This scenario introduces time transfer links from/to neighborhood locations which allow measurement between them, in order to have the performance under control and have an early fault detection mechanism. Depending on network operator's implementation strategy and roll-out time frame, this scenario may be not needed for specific networks.

Scenario 3

- Active usage of all available sources for local timescale generation.
- Scenario 3 provides the full cnPRTC functionality according to architectural concept as part of [ITU-T G.8275] in a very robust way to overcome any GNSS issues or any system defects. All sources will be used for local timescale generation including frequency, phase and time according to their individual assigned weight.

Table VII.1 provides an overview of the three deployment scenarios:

Table VII.1 – Summary of deployment secnario capabilities

Deployment scenario No.	**Used sources and logical functions**									**Descrip-tions**
	Local sources		**Remote sources**			**Logical functions**				
	PRC/ ePRC	PRTC	Time transfer links 1) from/to neighborhood e/cnPRTC nodes		UTC(k)	Measure ment function	Clock combiner function	Output function	GNSS Common view	
			for measure ment	for local ensem-bling 2)	from a remote UTC(k) lab					
1	Yes	Yes	No	No	Optional	Optional	Yes	Yes	Optional	Stand-alone ePRTC according to ITU-T G.8272.1
2	Yes	Yes	Yes	No		Yes	Yes	Yes		Like cnPRTC, but monitorin g the remote sources only
3	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Final cnPRTC architectu re, remote sources are actively used

1) e.g. IEEE 1588v2.1 (High-accuracy profile), or ITU-T PTP-FTS/SyncE.

2 To contribute to local time.

Appendix VIII

Description of PTP clock modes and associated contents of Announce messages

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

VIII.1 Purpose of this appendix

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

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

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

Network deployments including clocks using the procedures of this appendix are under the operator's responsibility.

VIII.2 Description of the modes

– <u>Free-Run mode</u>

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

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

– <u>Acquiring mode</u>

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

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

– <u>Locked mode</u>

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

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

– <u>Holdover-in-specification mode</u>

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

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

– Holdover-out-of-specification mode

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

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

VIII.3 Example of mapping between PTP port states and PTP clock modes for a 3-port T-BC/T-BC-P/T-BC-A

Table VIII.1 – PTP port state vs clock mode mapping

Telecom boundary clock					
	Port state			**Clock mode**	
Trigger event	**Port 1**	**Port 2**	**Port 3**		**Notes**
Power up of PTP	INITIALIZING	INITIALIZING	INITIALIZING	Free-run	No port in MASTER, PASSIVE, UNCALIBRATED, or SLAVE
Clock completes initialization	LISTENING	LISTENING	LISTENING	Free-run	No port in MASTER, PASSIVE, UNCALIBRATED, or SLAVE
Qualified *Announce* received from foreign master on port P1	UNCALIBRATED	LISTENING	LISTENING	Acquiring	A port is in UNCALIBRATED state
ANNOUNCE_RECEIPT_TIMEOUT_EXPIRES event on ports P2 and P3	UNCALIBRATED	MASTER	MASTER	Acquiring	A port is in UNCALIBRATED state
Calibration finished on port P1	SLAVE	MASTER	MASTER	Locked	A Slave port exists on the node
ANNOUNCE_RECEIPT_TIMEOUT_EXPIRES event on port P1	MASTER	MASTER	MASTER	Holdover-in-specification	Start holdover timer No port in SLAVE, UNCALIBRATED, LISTENING, or INITIALIZING
Holdover timer expires	MASTER	MASTER	MASTER	Holdover-out-of-specification	Holdover timer expired and no port in SLAVE, UNCALIBRATED, LISTENING, or INITIALIZING
Port P3 receives qualified *Announce* with clockClass = 7	MASTER	MASTER	UNCALIBRATED	Acquiring	A port is in UNCALIBRATED state
Calibration finished on port P3	MASTER	MASTER	SLAVE	Locked	A Slave port exists on the node
Port P1 receives qualified *Announce* with clockClass = 6	UNCALIBRATED	MASTER	PRE_MASTER	Acquiring	A port is in UNCALIBRATED state

Table VIII.1 – PTP port state vs clock mode mapping

Telecom boundary clock					
	Port state			Clock mode	
Trigger event	**Port 1**	**Port 2**	**Port 3**		**Notes**
QUALIFICATION_TIMEOUT_EXPIRES event on port P3	UNCALIBRATED	MASTER	MASTER	Acquiring	A port is in UNCALIBRATED state
Calibration finished on port P1	SLAVE	MASTER	MASTER	Locked	A Slave port exists on the node

VIII.4 T-GM Announce message contents based on the internal PTP clock modes

Table VIII.2 – T-GM Announce message contents

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

Table VIII.2 – T-GM Announce message contents

Announce message fields	Free-run mode	Acquiring mode	Locked mode	Holdover-in-specification mode	Holdover-out-of-specification mode
		previous state 7/140/150/160/248			
grandmasterClockQuality.clockAccuracy	Unknown (0xFE)	Unknown (0xFE)	0x21, 0x20	Unknown (0xFE)	Unknown (0xFE)
grandmasterClockQuality.offsetScaledLogVariance	0xFFFF (default)	0xFFFF (default)	0x4E5D, 0x4B32	0xFFFF (default)	0xFFFF (default)
grandmasterPriority2	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM	Configured priority2 of the T-GM
grandmasterIdentity	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T-GM	Local clockId of the T GM
stepsRemoved	0	0	0	0	0
timeSource	INT_OSC (0xA0)	INT_OSC (0xA0)	As per PTP	INT_OSC (0xA0)	INT_OSC (0xA0)
synchronizationUncertain (header.flagField)	TRUE (Note 3)	TRUE	FALSE (Note 3)	FALSE (Note 3)	TRUE (Note 3)

NOTE 1 – Time Properties (leap61, leap59, currentUtcOffsetValid, currentUtcOffset) can be obtained from time source (GNSS or TOD) or user configuration.

NOTE 2 – For more detail, refer to the applicable profile, ITU-T G.8275.1 (Table A.8) or ITU-T G.8275.2 (Table A.6).

NOTE 3 – Or as defined in Annex D.

VIII.5 T-BC/T-BC-P/T-BC-A Announce message contents based on the internal PTP clock modes

Table VIII.3 – T-BC/T-BC-P/T-BC-A Announce message contents

Announce message fields	Free-Run mode	Acquiring mode	Locked mode	Holdover-In-Specification mode	Holdover-Out-Of-Specification mode
sourcePortIdentity (header.sourcePortIdentity)	Local clockId of the T-BC/T-BC-P/T-BC-A + Port Number	Local clockId of the T-BC/T-BC-P/T-BC-A + Port Number	Local clockId of the T-BC/T-BC-P/T-BC-A + Port Number	Local clockId of the T-BC/ T-BC-P/T-BC-A + Port Number	Local clockId of the T-BC/T-BC-P/T-BC-A + Port Number
leap61 (header.flagField)	FALSE	(Note 1)	(Note 1)	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation specific] (Note 2)
leap59 (header.flagField)	FALSE	(Note 1)	(Note 1)	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation specific] (Note 2)
currentUtcOffsetValid (header.flagField)	FALSE	Implementation specific, generally previous state. TRUE/FALSE	(Note 1)	TRUE/FALSE (Note 2)	TRUE/FALSE [Implementation Specific] (Note 2)

Table VIII.3 – T-BC/T-BC-P/T-BC-A Announce message contents

Announce message fields	Free-Run mode	Acquiring mode	Locked mode	Holdover-In-Specification mode	Holdover-Out-Of-Specification mode
ptpTimescale (header.flagField)	TRUE	TRUE	(Note 1)	TRUE	TRUE
timeTraceable (header.flagField)	FALSE	Implementation specific, generally previous state. TRUE/FALSE	(Note 1)	TRUE	FALSE
frequencyTraceable (header.flagField)	TRUE/ FALSE based on Frequency Source lock	TRUE/FALSE based on Frequency Source lock	(Note 1)	TRUE/FALSE based on Frequency Source lock	TRUE/FALSE based on Frequency Source lock
currentUtcOffset	As per PTP	Last known UTC offset	(Note 1)	Last known UTC offset	Last known UTC offset (Note 2)
grandmasterPriority1	128 (default)	128 (default)	(Note 1)	128 (default)	128 (default)
grandmasterClockQuality. clockClass	248	Implementation specific, generally previous state. 135/165/248	(Note 1)	135	165
grandmasterClockQuality. clockAccuracy	Unknown (0xFE)	Unknown (0xFE)	(Note 1)	Unknown (0xFE)	Unknown (0xFE)
grandmasterClockQuality. offsetScaledLogVariance	0xFFFF (default)	0xFFFF (default)	(Note 1)	0xFFFF (default)	0xFFFF (default)
grandmasterPriority2	Configured priority2 of the T-BC/T-BC-P/T-BC-A	Configured priority2 of the T-BC/T-BC-P/T-BC-A	(Note 1)	Configured priority2 of the T-BC/T-BC-P/T-BC-A	Configured priority2 of the T-BC/T-BC-P/T-BC-A
grandmasterIdentity	Local clockId of the T-BC/T-BC-P/T-BC-A	Local clockId of the T-BC/T-BC-P/T-BC-A	(Note 1)	Local clockId of the T-BC/T-BC-P/T-BC-A	Local clockId of the T-BC/T-BC-P/T-BC-A
stepsRemoved	0	0	Received stepsRemoved +1	0	0
timeSource	INT_OSC (0xA0)	INT_OSC (0xA0)	(Note 1)	INT_OSC (0xA0)	INT_OSC (0xA0)
synchronizationUncertain (header.flagField)	TRUE (Note 5)	TRUE	(Note 4)	(Note 4)	(Note 4)

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

NOTE 2 – Refer to the applicable profile, ITU-T G.8275.1 (Table A.8) or ITU-T G.8275.2 (Table A.6), for more detail.

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

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

NOTE 5 – Or as defined in Annex D.

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