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International Telecommunication Union
Standardization Sector

Recommendation

ITU-T G.781.1 (2022) Amd. 1 (11/2022)

SERIES G: Transmission systems and media, digital systems and networks

Digital terminal equipments – Principal characteristics of multiplexing equipment for the synchronous digital hierarchy

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Synchronization layer functions for packet-based synchronization

Amendment 1

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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Recommendation ITU-T G.781.1

Synchronization layer functions for packet-based synchronization

Amendment 1

Summary

Recommendation ITU-T G.781.1 specifies a functional architecture model and corresponding atomic functions for the transport of time and frequency synchronization via packet-based methods using the precision time protocol (PTP).

Amendment 1 to Recommendation ITU-T G.781.1 provides the following updates:

- Addition of FlexO to SD packet-based sync adaptation functions
- Minor corrections and clarifications.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.781.1	2022-02-13	15	11.1002/1000/14914
1.1	ITU-T G.781.1 (2022) Amd. 1	2022-11-13	15	11.1002/1000/15138

Keywords

Atomic function, functional model, network synchronization layer, packet-based, quality level (QL), synchronization distribution layer, synchronization

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

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Recommendation ITU-T G.781.1

Synchronization layer functions for packet-based synchronization

Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.781.1 (2022).

1 Scope

This Recommendation specifies a functional architecture model and corresponding atomic functions for the transport of time and frequency synchronization via packet-based methods using [ITU-T G.8275.1] and [ITU-T G.8275.2]. The specification related to the transport of frequency synchronization via packet-based methods using [ITU-T G.8265.1] is for further study. The functional architecture contains the following synchronization layers: the network synchronization packet (NS-p) layer, the synchronization distribution packet (SD-p) layer, and the SD-t for the synchronization distribution of time information (e.g., via 1PPS+ToD). In addition, some of the synchronization-related atomic functions defined in this Recommendation are part of the transport layer.

The atomic functions specified in this Recommendation can be combined in accordance with the functional architecture model to describe the time and frequency synchronization transport functionality of network equipment.

2 References

The following ITU-T Recommendations and other references contain provisions that, 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.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks*.

[ITU-T G.8260] Recommendation ITU-T G.8260 (~~2020~~2022), *Definitions and terminology for synchronization in packet networks*.

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

[ITU-T G.8265.1] Recommendation ITU-T G.8265.1/Y.1365.1 (~~2021~~2022), *Precision time protocol telecom profile for frequency synchronization*.

[ITU-T G.8266] Recommendation ITU-T G.8266/Y.1376 (2016), *Timing characteristics of telecom grandmaster clocks for frequency synchronization*.

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

[ITU-T G.8272.1] Recommendation ITU-T G.8272.1/Y.1367.1 (2016), *Timing characteristics of enhanced primary reference time clocks*.

[ITU-T G.8273.2] Recommendation ITU-T G.8273.2/Y.1368.2 (2020), *Timing characteristics of telecom boundary clocks and telecom time slave clocks for use with full timing support from the network.*

[ITU-T G.8273.3] Recommendation ITU-T G.8273.3/Y.1368.3 (2020), *Timing characteristics of telecom transparent clocks for use with full timing support from the network.*

[ITU-T G.8273.4] Recommendation ITU-T G.8273.4/Y.1368.4 (2020), *Timing characteristics of telecom boundary clocks and telecom time slave clocks for use with partial timing support from the network.*

[ITU-T G.8275] Recommendation ITU-T G.8275/Y.1369 (2020), *Architecture and requirements for packet-based time and phase distribution*.

[ITU-T G.8275.1] Recommendation ITU-T G.8275.1/Y.1369.1 (~~2020~~2022), *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~~2022), *Precision time protocol telecom profile for time/phase synchronization with partial timing support from the network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

Terms related to synchronization are defined in [ITU-T G.810] and [ITU-T G.8260].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI Adapted Information

AppCk Application Clock

BMCA Best Master Clock Algorithm

CI Characteristic Information

CP Connection Point

ePRTC enhanced Primary Reference Time Clock

FS Frame Start

GFP-F Frame-mapped Generic Framing Procedure

GNSS Global Navigation Satellite System

MFS Multiframe start

MI Management Information

NE Network Element

NS-p Packet-based Network Synchronization

OSC	Optical Supervisory Channel
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTU	Optical Transport Unit
PEC-M-F	Packet-based Equipment Clock – Master – Frequency
PEC-S-F	Packet-based Equipment Clock – Slave – Frequency
PPS	Pulse Per Second
PRTC	Primary Reference Time Clock
PTP	Precision Time Protocol
PTSF	Packet Timing Signal Fail
QL	Quality Level
SD-p	Packet-based Synchronization Distribution
SD-t	Synchronization Distribution time (e.g., 1PPS+ToD)
Sk	Sink
So	Source
T-BC	Telecom Boundary Clock
T-BC-A	Telecom Boundary Clock for Assisted partial timing support
T-BC-P	Telecom Boundary Clock for Partial timing support
T-GM	Telecom Grandmaster
TM	Synchronized Time
ToD	Time of Day
TRef	Time Reference
TS	Timestamp
TT	Trail Termination
T-TC	Telecom Transparent Clock
T-TSC	Telecom Time Slave Clock
T-TSC-A	Telecom Time Slave Clock for Assisted partial timing support
T-TSC-P	Telecom Time Slave Clock for Partial timing support

5 Conventions

None.

6 Packet-based synchronization functional model and general principles

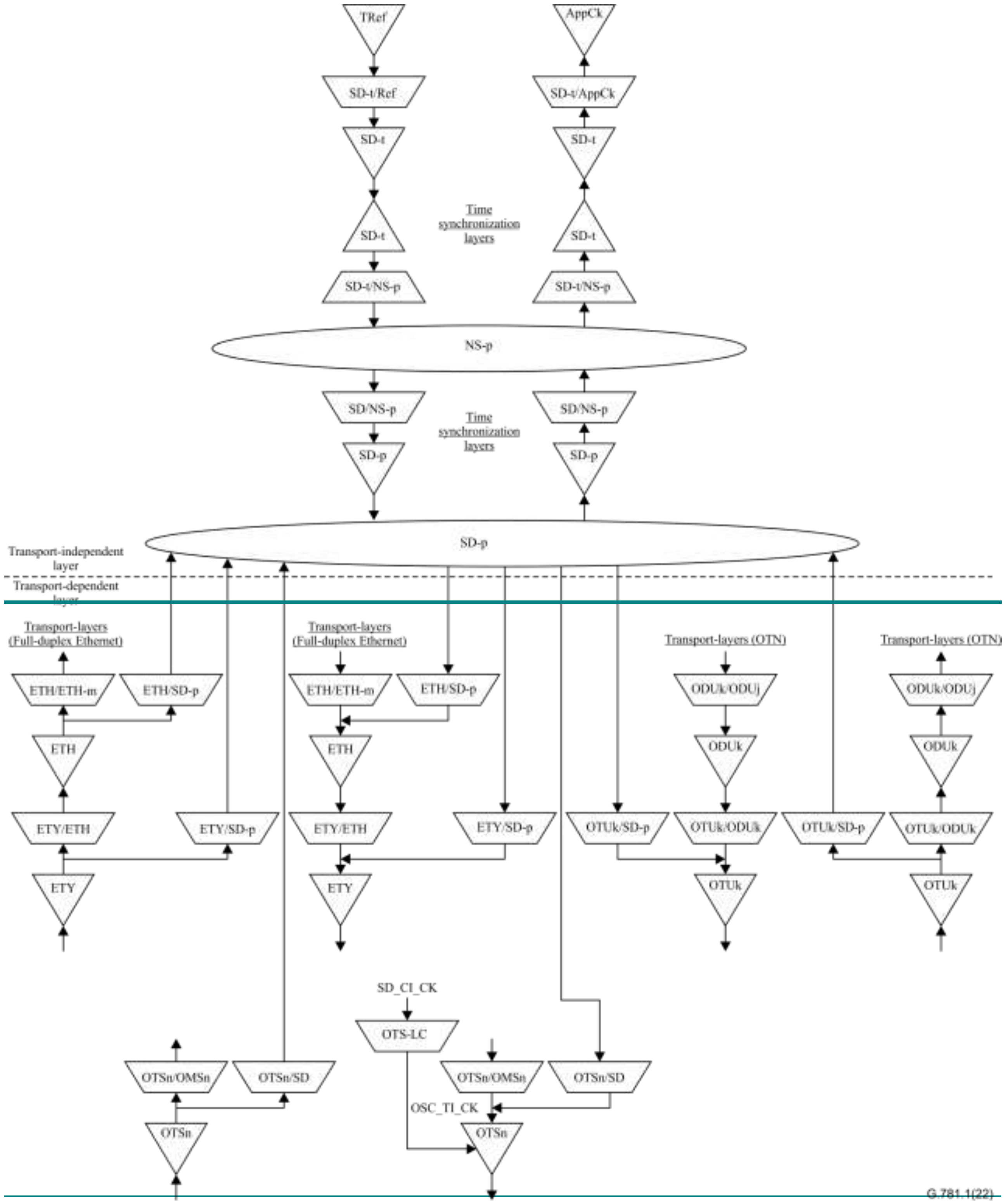
6.1 Packet-based synchronization functional model

Packet-based synchronization information is transmitted through the network via timing protocols. The synchronization distribution chains consist of precision time protocol (PTP) interfaces and external time interfaces such as one pulse per second (1PPS). PTP can be carried through the network by various transport media. The alternate best master clock algorithm (BMCA) is run locally on the ports of every telecom time slave clock (T-TSC) and telecom boundary clock (T-BC) to determine the recommended PTP port state and select the best (TRef) time reference signal, as defined in [ITU-T G.8275.1] and [ITU-T G.8275.2].

Currently, PTP messages are specified over Ethernet and optical transport network (OTN) transports. Figure 6-1 illustrates the high-level functional architecture for the transport of packet-based synchronization via PTP over full-duplex Ethernet and OTN transports. The primary reference time clock (PRTC) receives a reference time (TRef in Figure 6-1). The synchronization signal is distributed by transport-dependent layers, including Ethernet trail, OTN optical transport unit (OTU) trail, OTN optical supervisory channel (OSC) trail, etc. The end application extracts the synchronization signals from the packet-based synchronization networks.

Packet-based synchronization distribution (SD-p) trails transport synchronization signals between two adjacent pieces of equipment. Packet-based network synchronization (NS-p) connection transports the synchronization signal over a series of synchronization link connections.

Figure 6-2 illustrates an example of a series of packet-based synchronization distribution network connections transporting PRTC-quality timing reference information.


TRef
AppCk
SD-t/Ref
SD-t/AppCk
SD-t
SD-t
Time synchronization layers
SD-t
SD-t
SD-t/NS-p
SD-t/NS-p
NS-p
SD/NS-p
SD/NS-p
Time synchronization layers
SD-p
SD-p
SD-p
Transport-independent layer
Transport-dependent layer
Transport-layers (Full-duplex Ethernet)
Transport-layers (Full-duplex Ethernet)
Transport-layers (OTN)
Transport-layers (OTN)
ETH/ETH-m
ETH/SD-p
ETH/ETH-m
ETH/SD-p
ODUk/ODUj
ODUk/ODUj
ETH
ETH
ODUk
ODUk
ETY/ETH
ETY/SD-p
ETY/ETH
ETY/SD-p
OTUk/SD-p
OTUk/ODUk
OTUk/SD-p
OTUk/ODUk
ETY
ETY
OTUk
OTUk
SD_CI_CK
OTS-LC
OTSn/OMSn
OTSn/SD
OTSn/OMSn
OTSn/SD
OSC_TI_CK
OTSn
OTSn
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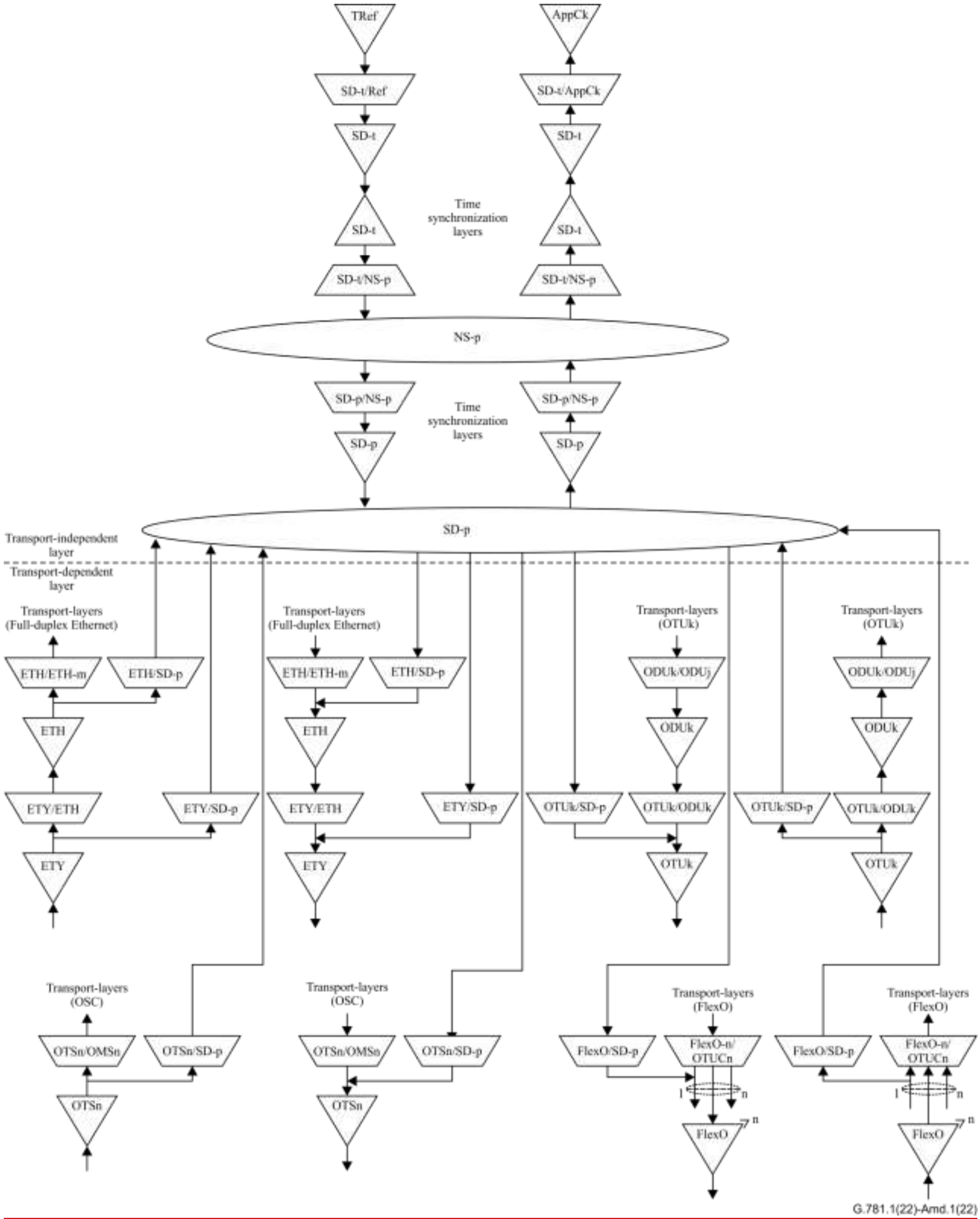

Figure 6-1 – High-level functional architecture for transport of packet-based synchronization via PTP over full-duplex Ethernet and OTN transports

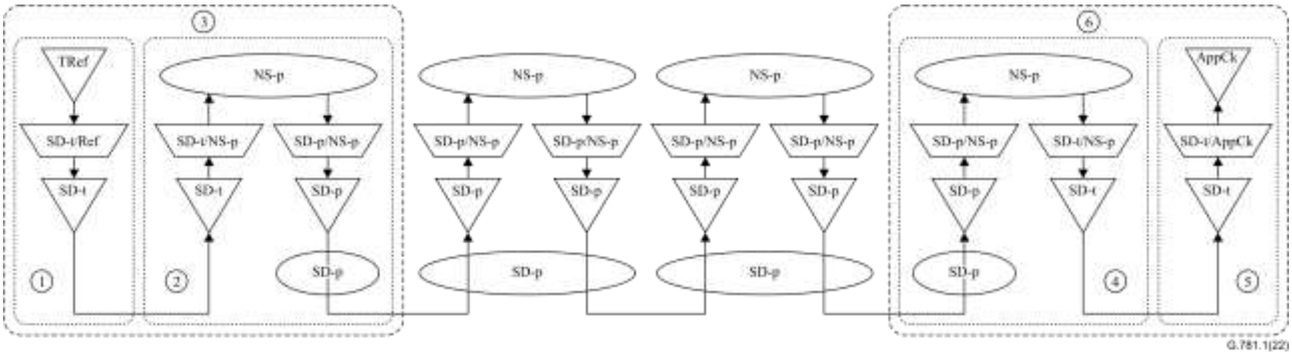

Figure 6-2 – Example of series of packet-based synchronization distribution network connections transporting PRTC-quality timing reference information

NOTE 1 – Part ① is the functional model of PRTC, part ② is a functional model of the telecom grandmaster (T-GM), and part ③ is a function model of PRTC integrated with T-GM.

NOTE 2 – For a clock integrating PRTC and T-GM in the same equipment, the link between the part ① and ② is internal and it is implementation specific, which is not accessible.

NOTE 3 – Part ④ is a functional model of the PTP slave clock, part ⑤ is a function model of the application device and part ⑥ is a function model of the application device integrated with the PTP slave clock.

NOTE 4 – For a clock integrating PTP slave clock and the application device in the same equipment, the link between part ④ and part ⑤ is implementation specific, which is not accessible.

NOTE 5 – Figure 6-2 shows an example of synchronization timing flow from a PRTC to the end application, and it does not show the message flow.

6.2 Synchronization interfaces

Currently, the following synchronization interfaces are defined:

– enhanced primary reference time clock (ePRTC) interfaces in [ITU-T G.8272.1]

– PRTC interfaces in [ITU-T G.8272]

– T-BC and T-TSC interfaces in [ITU-T G.8273.2]

– Telecom transparent clock (T-TC) interfaces in [ITU-T G.8273.3]

– Telecom boundary clock for assisted partial timing support (T-BC-A), telecom boundary clock for partial timing support (T-BC-P), telecom time slave clock for assisted partial timing (T-TSC-A), and telecom time slave clock for partial timing support (T-TSC-P) interfaces in [ITU-T G.8273.4]

– Packet-based equipment clock – master – frequency (PEC-M-F) interfaces in [ITU-T G.8266]

– Packet-based equipment clock – slave – frequency (PEC-S-F) interfaces in [ITU-T G.8263].

6.3 Automatic reference selection process (alternate BMCA)

The automatic reference selection processes are based on the alternate BMCA defined in [ITU-T G.8275.1] and [ITU-T G.8275.2], which is performed in the NS-p packet-based sync connection function (NS-p_C). The input signals for the time reference selection processes include not only the input time signal packet-based network synchronization characteristic information (NS-p_CI), but also the input frequency quality level (NS_CI_QL). The input frequency quality level (QL) will influence the frequencyTraceable flag and the clockClass value in the holdover.

The defaultDS.slaveOnly and portDS.masterOnly attributes are configurable to help network planning.

6.4 PTP Announce message delay times for NEs

For the time synchronization, the quality level of the PTP clock is carried by the Announce message. The Announce message is sent based on its message interval. For example, the nominal rate of Announce message of [ITU-T G.8275.1] is 8 packets-per-second, so the mean message interval is 125 ms.

The Announce message delay times include the PTP holdover message delay (T_{PHM}), non-switching PTP message delay (T_{PNSM}), and the switching PTP message delay (T_{PSM}).

A detailed analysis of the message delay times is given in Appendix III. The values are for further study.

6.5 Overview of the processes performed within the atomic functions

A list of the time synchronization atomic functions and a short description of their functionality is given in Table 6-1. For a more detailed description, see clauses 7 to 9.

Table 6-1 – Functional overview of atomic functions

Atomic function	Functionality
NS-p_C	PTP functions invoked by the clock, including the data set comparison and the state decision by alternate BMCA, the subsequent updating of PTP data sets and PTP time.
SD-p_C	Preselection of transport interfaces as possible time sources whose port state is not INITIALIZING, FAULTY, OR DISABLED.
SD-p_TT_Sk	PTP functions that are transport-independent and port-specific, including the computation of E_{rbest}, passing through of the incoming PTP time.
SD-p_TT_So	Pass through time synchronization and best master clock selection information to the transport-dependent layer for the port.
SD-p/NS-p_A_Sk	A virtual E_{rbest} is associated with the external phase/time input. The values are assigned to the virtual E_{rbest} for the subsequent data set comparison of E_{best}.
SD-p/NS-p_A_So	Adaptation of the best master clock selection information to the external phase/time information.
SD-t/TRef_A_So	Accept the time information from a time reference (TRef) and generates time information (e.g., via a 1 PPS+ToD interface)
SD-t/AppCk_A_Sk	Accept the PTP time information (e.g., via a 1 PPS+ToD interface) and generates the desired time format for the application.
SD-t_TT_Sk	Time functions that are transport-independent and port-specific, passing through of incoming time (e.g., via a 1 PPS+ToD interface).
SD-t_TT_So	Pass through time information (e.g., via a 1 PPS+ToD interface).
XX/SD-p_A_Sk	Process the received PTP event messages. Extract the timestamp (TS) and other information. Calculate the correctionField. Pass through received Announce message information.
XX/SD-p_A_So	Send the PTP event messages. Prepare and compute the fields for the transmitted PTP messages. Pass through Announce message information.
NOTE – 'XX' represents ~~ETY~~ETH, ~~ODUk~~OTUk, ~~or~~ ~~OSC~~OTSn, FlexE, or FlexO.	

7 Network synchronization layer atomic functions

Within this layer, the same connection function is used for the source selection processes which may have different types of reference sources:

– a PTP reference;

– a virtual PTP reference, e.g., 1PPS+ToD or the global navigation satellite system (GNSS).

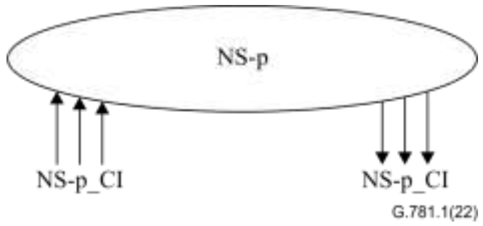

Figure 7-1 – Network synchronization PTP layer atomic functions

NS layer CP

The CI at this point is a clock signal with the associated members necessary for the BMC algorithm.

7.1 NS-p connection function (NS-p_C)

Symbol:

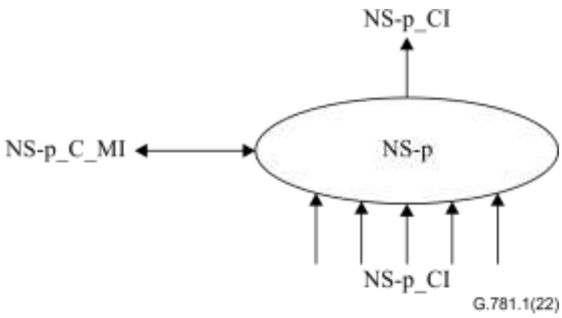

Figure 7-2 – NS-p_C symbol

Interfaces:

Table 7-1 – NS-p_C input and output signals

Input(s)	Output(s)
Per input: NS-p_CI_E_{rbest} NS-p_CI_TS NS-p_C_MI_portDS.localPriority NS-p_C_MI_portDS.masterOnly Per function: NS-p_CI_D_0 NS-p_CI_defaultDS.localPriority	Per function: NS-p_CI_TS NS-p_CI_currentDS NS-p_CI_parentDS NS-p_CI_timePropertiesDS NS-p_CI_portState NS-p_C_MI_SelectedInput

NOTE 1 – The NS-p_CI_E_{rbest} (the best data set of each port), NS-p_C_E_{best} (the best data set of all E_{rbest}) and the NS-p_CI_D_0 (the local data set) are required by [ITU-T G.8275.1] and [ITU-T G.8275.2].

Processes:

This function performs PTP source selection processes, which selects a synchronization source out of the nominated set of synchronization source inputs determined by the alternate BMC algorithm of [ITU-T G.8275.1] or [ITU-T G.8275.2].

The configuration of the member NS-p_C_MI_portDS.localPriority shall be consistent with portDS.localPriority of [ITU-T G.8275.1] and [ITU-T G.8275.2], including its default value and range.

The configuration of the member NS-p_C_MI_portDS.masterOnly shall be consistent with portDS.masterOnly of [ITU-T G.8275.1] and [ITU-T G.8275.2], including its default value and range. The use of this member by the NS-p_C function shall comply with the definition of the respective profiles.

NOTE 2 – The number of input signals to the connection process and the number of connection processes in the function are not specified in this Recommendation. It is the property of the individual network elements (NE).

Status report:

The actual selected source of a selection process shall be reported via management information MI_SelectedInput.

Defects: For further study.

NOTE 3 – The time unlock defect, time of day (ToD) (or PTP) input degradation, and the time offset/accumulated time offset over the limit defect are for further study.

Defect correlations: None.

Performance monitoring: For further study.

NOTE 4 – The PTP time offset/accumulated time offset monitoring, and the time error measurement by reference comparison in the performance monitoring (including the use of a passive port), are for further study.

8 Synchronization distribution layer atomic functions

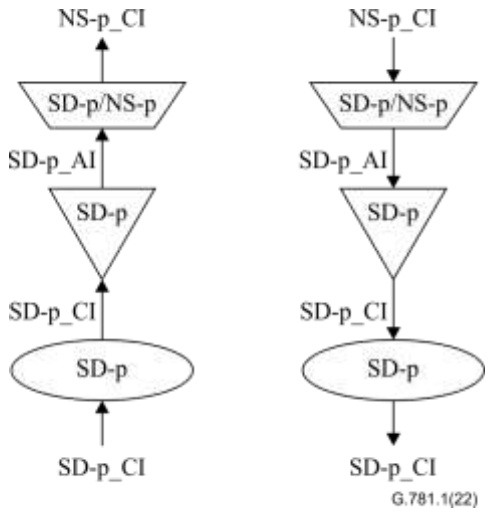

Figure 8-1 – Synchronization distribution layer atomic functions

SD layer CP

The characteristic information (CI) at this point is a packet-based synchronization signal with data set members extracted from the messages.

SD layer AP

The adapted information (AI) at this point is a packet-based synchronization signal with data set members extracted from the messages.

8.1 SD-p connection function (SD-p_C)

8.1.1 SD-p connection source function (SD-p_C_So)

Symbol:

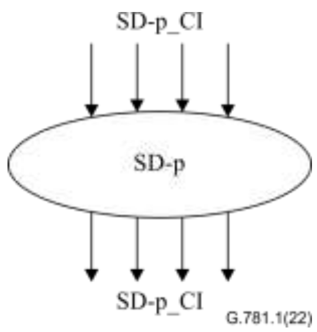

Figure 8-2 – SD-p_C_So symbol

Interfaces:

Table 8-1 – SD-p_C_So input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_TM	SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_TM

Processes:

The SD-p_C_So function selects the ports whose port state is not INITIALIZING, FAULTY, OR DISABLED, then passes through time synchronization and best master clock selection information, received from the SD-p_TT_So function to the transport-dependent layer source function for only the non-initializing, faulty and disabled ports.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.1.2 SD-p connection sink function (SD-p_C_Sk)

Symbol:

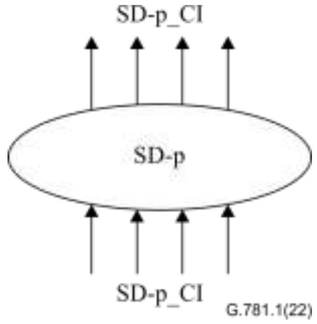

Figure 8-3 – SD-p_C_Sk symbol

Interfaces:

Table 8-2 – SD-p_C_Sk input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_portState If the port state is SLAVE, including: SD-p_CI_TS	SD-p_CI_AnnounceFields SD-p_CI_portState If the port state is SLAVE, including: SD-p_CI_TS

Processes:

The SD-p_C_Sk function selects the transport-dependent layer source adaptation functions of ports whose port state is not INITIALIZING, FAULTY, OR DISABLED, and provides input to the SD-p_TT_Sk function.

The data set members extracted from the PTP messages of the ports whose port state is not INITIALIZING, FAULTY, OR DISABLED are passed through from input connection points (CP) to the output connection points.

If an output of this function is not connected to one of its inputs, the data set at the output is empty.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.2 Trail termination (TT) functions

8.2.1 SD-p trail termination functions (SD-p_TT_So and SD-p_TT_Sk)

8.2.1.1 SD-p trail termination source function (SD-p_TT_So)

Symbol:

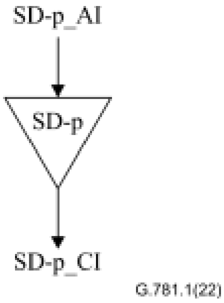

Figure 8-4 – SD-p_TT_So symbol

Interfaces:

Table 8-3 – SD-p_TT_So input and output signals

Input(s)	Output(s)
SD-p_AI_AnnounceFields SD-p_AI_portState SD-p_AI_TM	SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_TM

Processes:

The SD-p_TT_So function passes through time synchronization and best master clock selection information, received from the SD/NS-p_A_So function to the SD-p_C_So function for the port.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.2.1.2 SD-p trail termination sink function (SD-p_TT_Sk)

Symbol:

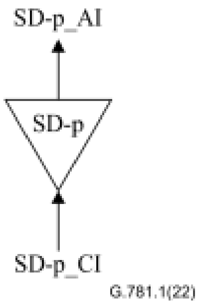

Figure 8-5 – SD-p_TT_Sk symbol

Interfaces:

Table 8-4 – SD-p_TT_Sk input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_portState If the port state is SLAVE, including: SD-p_CI_TS	SD-p_AI_AnnounceFields SD-p_AI_portState If the port state is SLAVE, including: SD-p_AI_TS

Processes:

This function includes passing through of incoming PTP information from the Announce messages and/or time stamps corresponding to event messages if the port state is SLAVE.

The member SD-p_CI_TS is PTP timing information of a PTP port, including:

a) originTimestamp and correctionField of the Sync message received by the port;

b) preciseOriginTimestamp and correctionField of the Follow_Up message received by the port, if a two-step mode is used;

c) receiveTimestamp and correctionField of the Delay_Resp message received by the port; and

d) the local timeStamp generated by the port when the PTP event message is received or transmitted.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.2.2 SD-t trail termination functions (SD-t_TT_So and SD-t_TT_Sk)

8.2.2.1 SD-t trail termination source function (SD-t_TT_So)

8.2.2.1.1 SD-t trail termination source function of PRTC

Symbol:

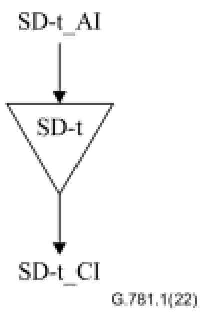

Figure 8-6 – SD-t_TT_So symbol of PRTC

Interfaces:

Table 8-5 – SD-t_TT_So input and output signals of PRTC

Input(s)	Output(s)
SD-t_AI_TM SD-t_AI_Status	SD-t_CI_TM SD-t_CI_Status

Processes:

This function passes through the time and GNSS status information from the SD-t/TRef_A_So function to the 1PPS+ToD transport layer.

The member SD-t_AI_TM is the accurate time received from the SD-t/Tref_A_So function.

The member SD-t_AI_Status is the reference status information received from the SD-t/Tref_A_So function.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.2.2.1.2 SD-t trail termination source function of PTP slave clock

Symbol:

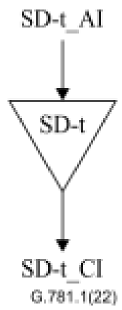

Figure 8-7 – SD-t_TT_So symbol of PTP slave clock

Interfaces:

Table 8-6 – SD-t_TT_So input and output signals of PTP slave clock

Input(s)	Output(s)
SD-t_AI_AnnounceFields SD-t_AI_TM	SD-t_CI_AnnounceFields SD-t_CI_TM

Processes:

This function passes through the time and announce information from the SD-t/NS-p_A_So function to the 1PPS+ToD transport layer.

The member SD-t_AI_AnnounceFields is the information received from the SD-t/NS-p_A_So function.

The member SD-t_AI_TM is the accurate time received from SD-t/NS-p_A_So function.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.2.2.2 SD-t trail termination sink function (SD-t_TT_Sk)

8.2.2.2.1 SD-t trail termination sink function of T-GM

Symbol:

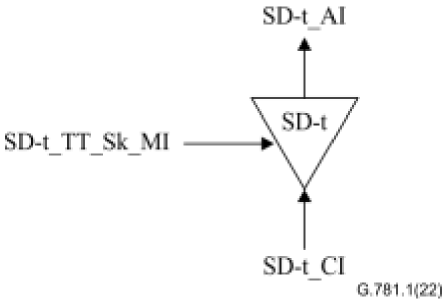

Figure 8-8 – SD-t_TT_Sk symbol of T-GM

Interfaces:

Table 8-7 – SD-t_TT_Sk input and output signals of T-GM

Input(s)	Output(s)
SD-t_TT_Sk_MI_AnnounceFields SD-t_TT_Sk_MI_portDS.localPriority SD-t_TT_Sk_MI_portDS.masterOnly If the port state is SLAVE, including: SD-t_CI_TS	$SD\text{-}t\_AI\_E_{rbest}$ If the port state is SLAVE, including: SD-t_AI_TS

The member $SD\text{-}t\_AI\_E_{rbest}$ shall include all the members used by the alternate BMC algorithm of [ITU-T G.8275.1] and [ITU-T G.8275.2], respectively.

Processes:

This function terminates a synchronization trail transmitted via the 1PPS+ToD interface of a T-GM, and processes and reports the incoming quality and timing information.

The SD-t_TT_Sk function includes the computation of E_{rbest}, which shall comply with Annex B of [ITU-T G.8275].

This also includes passing through of the incoming ToD time from a transport-dependent layer source function of the slave port.

The member SD-t_TT_Sk_MI_AnnounceFields is to configure some fields at the egress 1PPS+ToD port, and it shall be consistent with Annex B of [ITU-T G.8275].

The member SD-t_TT_Sk_MI_portDS.localPriority shall be consistent with portDS.localPriority of [ITU-T G.8275.1] and [ITU-T G.8275.2], including its default value and range.

The member SD-t_TT_Sk_MI_portDS.masterOnly shall be consistent with portDS.masterOnly of [ITU-T G.8275.1] and [ITU-T G.8275.2], including its default value and range. The use of this member by the SD-t_TT_Sk function shall comply with the definition of the respective PTP profiles.

The member SD-t_CI_TS is timing information of a 1PPS+ToD port, including:

a) Time field of the time event message received by the 1PPS+ToD port; and

b) the local timeStamp generated by the port when the time event message is received.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.2.2.2.2 SD-t trail termination sink function of an application device

Symbol:

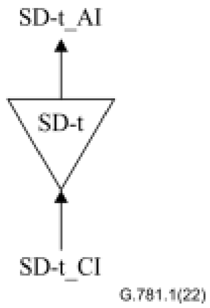

Figure 8-9 – SD-t_TT_Sk symbol of an application device

Interfaces:

Table 8-8 – SD-t_TT_Sk input and output signals of an application device

Input(s)	Output(s)
SD-t_CI_AnnounceFields SD-t_CI_TS	SD-t_AI_TS

Processes:

This function terminates a synchronization trail transmitted via the 1PPS+ToD interface of an application device, processes and reports the incoming quality and timing information.

This also includes passing through of the incoming ToD time from a transport-dependent layer source function.

The member SD-t_CI_AnnounceFields are fields carried by the time Announce message of the 1PPS+ToD link.

The member SD-t_CI_TS is the PTP timing information of a PTP port, including:

a) Time field of the time event message received by the 1PPS+ToD port; and

b) the local timeStamp generated by the port when the time event message is received.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.3 Adaptation functions

8.3.1 SD-p layer to NS-p layer adaptation functions (SD-p/NS-p_A_So and SD-p/NS-p_A_Sk)

8.3.1.1 SD-p layer to NS-p layer adaptation source function (SD-p/NS-p_A_So)

Symbol:

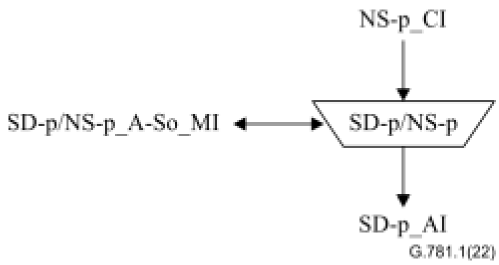

Figure 8-10 – SD-p/NS-p_A_So symbol

Interfaces:

Table 8-9 – SD-p/NS-p_A_So input and output signals

Input(s)	Output(s)
NS-p_CI_currentDS NS-p_CI_parentDS NS-p_CI_timePropertiesDS NS-p_CI_portState NS-p_CI_TM NS-p_CI_QL SD-p/NS-p_A_So_MI_CkOperation	SD-p_AI_AnnounceFields SD-p_AI_portState SD-p_AI_TM SD-p/NS-p_A_So_MI_CkMode SD-p/NS-p_A_So_MI_cCkModeS

Processes:

This function extracts the fields from NS-p_CI_currentDS, NS-p_CI_parentDS and NS-p_CI_timePropertiesDS, which are needed by the header of the PTP messages and the payload of the Announce messages and converts them as SD-p_AI_AnnounceFields.

This function generates a system clock as defined in [ITU-T G.8263], [ITU-T G.8273.2], [ITU-T G.8273.3], and [ITU-T G.8273.4].

The function shall support three types of operation:

– forced free-run~~ning~~ operation working in the free-run mode;

– forced holdover operation, working in the holdover mode;

– normal operation, working in the acquiring, free-run, locked, or holdover mode depending on the input signals.

These three types of operation are activated by the user management input (CkOperation) while the modes are automatically activated by the status of the input signals. Figure 8-11 shows the relationship between the types of operation and modes.

Clock mode state diagram:

Clock operation can be described in terms of a state diagram as shown in Figure 8-11. Operation involves four modes: Free-run, acquiring, locked and holdover as described below. Transitions between the modes are generally automatic (for example, when a reference is either lost or restored). However, in some cases, management commands may force the transition from one mode to another, for example, locked to holdover. Forced transitions are for further study.

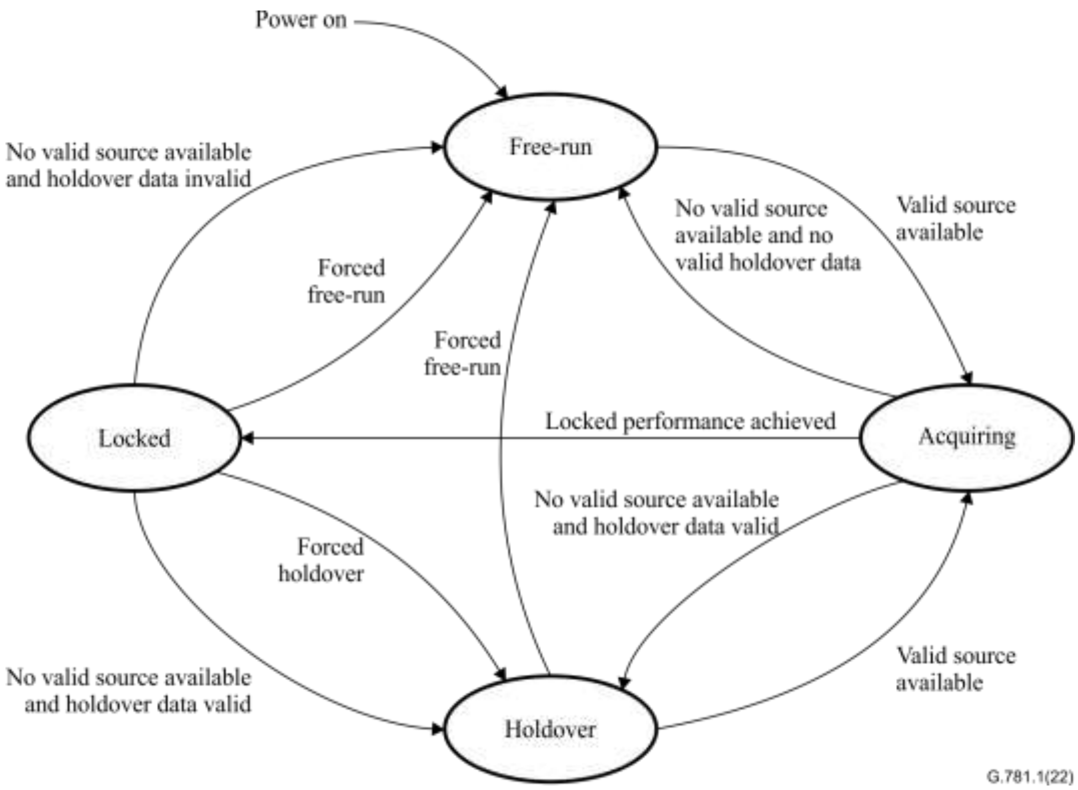

Figure 8-11 – Clock mode state transitions

Acquiring mode: An operating condition of a clock in which the clock has a valid signal present. In this mode, the clock is attempting to minimize the error between the internal clock and the incoming clock reference signal. During this time, the clock may be collecting information that it can use when it enters the holdover in the case of loss of the input signal. During the acquiring mode, the performance that could be achieved at the output may not meet the network requirements. The transition from acquiring to locked mode is implementation specific (and may vary depending on the network conditions).

Free-run mode: An operating condition of a clock, the output signal of which is strongly influenced by the oscillating element and not controlled by servo phase-locking techniques. In this mode, the clock has never had a network reference input, or the clock has lost external reference and has no access to stored holdover data that could be acquired from a previously connected external reference. Free-run begins when the clock output no longer reflects the influence of a connected external reference, or transitions from the external reference. Free-run terminates when the clock enters the acquiring mode.

NOTE 1 – The term "free-run" is equivalent to the term "free running" in [ITU-T G.810].

Holdover mode: An operating condition of a clock that has lost its controlling reference input and is using stored data, acquired while in acquiring and locked modes, to control its output. The stored data are used to control time, phase and frequency variations, allowing the locked condition to be reproduced within specifications. Holdover begins when the clock output no longer reflects the influence of a connected external reference, or transition from it. Holdover terminates when the clock enters the acquiring mode.

Locked mode: An operating condition of a slave clock in which the output signal is controlled by an external input reference such that the clock's output signal has the same long-term average frequency as the input reference, and the time error function between output and input is bounded. Locked mode is the expected mode of operation of a slave clock. Information stored to support the holdover mode may be updated while in this mode.

NOTE 2 – The above descriptions are based on [ITU-T G.810], with the last sentences of the descriptions of free-run mode and holdover mode modified, the addition of a sentence to the description of locked mode, and the addition of the description of the acquiring mode. These descriptions apply only to packet-based clocks.

The following table captures some transition events with descriptions.

Table 8-10 – Transition information

Mode	Event	Description
	Power on	The clock initializes and enters the free-run mode.
Free-run	Valid source available	Input reference selection has selected a valid reference to use to control the clock. The clock transitions to acquiring mode.
Acquiring	No valid source available and no valid holdover data	The current selected reference has become invalid and there are no other valid references available and no valid holdover data. The clock transitions to free-run mode.
	No valid source available and holdover data valid	The current selected reference has become invalid and there is no other valid reference available, and the holdover data is still valid. The clock transitions to holdover mode.
	Locked performance achieved	The clock determines that the expected performance output of the signal will be within performance limits. The clock transitions to locked mode.
Locked	No valid source available and holdover data valid	The current selected reference has become invalid, there are no other valid references available, and there is valid holdover data. The clock transitions to holdover mode.
	No valid source available and holdover data is not valid	The current selected reference has become invalid, there are no other valid references available, and there is no valid holdover data. The clock transitions to free-run mode.
	Forced holdover	Triggered by a management command. The clock no longer follows an input reference. The clock transitions to holdover mode.
	Forced free-run	Triggered by a management command. The clock stops using any input reference and enters free-run mode.
Holdover	Valid source available	Input reference selection has selected a valid reference to use to control the clock. The clock transitions to acquiring mode.
	Forced free-run	Triggered by a management command. The clock stops using any input reference and enters free-run mode.

Defects:

If the function receives the SD-p/NS-p_A_So_MI_CkOperation signal of forced free-running or forced holdover operation and switches its clock mode state, this function will detect a time synchronization status switch (dCkModeS).

Consequent actions: None.

Defect correlations:

cCkModeS $\leftarrow$ dCkModeS

Performance monitoring: None.

8.3.1.2 SD-p layer to NS-p layer adaptation sink function (SD-p/NS-p_A_Sk)

Symbol:

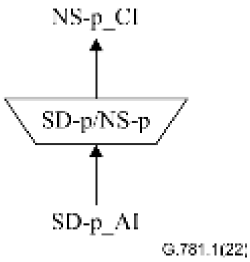

Figure 8-12 – SD-p/NS-p_A_Sk symbol

Interfaces:

Table 8-11 – SD-p/NS-p_A_Sk input and output signals

Input(s)	Output(s)
SD-p_AI_AnnounceFields SD-p_AI_portState If the port state is SLAVE, including: SD-p_AI_TS	NS-p_CI_E_{rbest} NS-p_CI_portState If the port state is SLAVE, including: NS-p_CI_TS

The member NS-p_AI_E_{rbest} shall include all members used by the alternate BMC algorithm of [ITU-T G.8275.1] and [ITU-T G.8275.2], respectively.

Processes:

This function includes the computation of E_{rbest} (see clause 6.3.1 of [ITU-T G.8275.1] and clause 6.7.1 of [ITU-T G.8275.2]). This function also passes through the E_{rbest} and/or PTP time stamps if the port state is SLAVE to the NS-p layer.

Defects: None.

NOTE – Packet timing signal fail (PTSF) is for further study.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.3.2 SD-t layer to NS-p layer adaptation functions (SD-t/NS-p_A_So and SD-t/NS-p_A_Sk)

8.3.2.1 SD-t layer to NS-p layer adaptation source function (SD-t/NS-p_A_So)

Symbol:

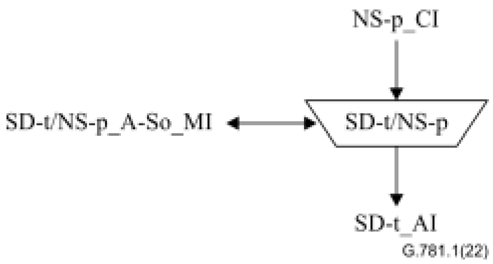

Figure 8-13 – SD-t/NS-p_A_So symbol

Interfaces:

Table 8-12 – SD-t/NS-p_A_So input and output signals

Input(s)	Output(s)
NS-p_CI_currentDS NS-p_CI_parentDS NS-p_CI_timePropertiesDS NS-p_CI_portState NS-p_CI_TM SD-t/NS-p_A_So_MI_CkOperation	SD-t_AI_AnnounceFields SD-t_AI_TM SD-t/NS-p_A_So_MI_CkMode SD-t/NS-p_A_So_MI_CkModeS

Processes:

This function generates a system clock as defined in [ITU-T G.8273.2] or [ITU-T G.8273.4]. The behaviour of the system clock refers to clause 8.3.1.

The member SD-t_AI_AnnounceFields is information translated from NS-p_CI_currentDS, NS-p_CI_parentDS and NS-p_CI_timePropertiesDS, which includes all the fields of time Announce message defined in clause A.1.3.3 of [b-ITU-T G.8271].

The member SD-t_AI_TM is the accurate time recovered by the system clock.

Defects:

If the function receives the SD-t/NS-p_A_So_MI_CkOperation signal of forced free-run~~ning~~ or forced holdover operation and switches its clock mode state, this function will detect a time synchronization status switch (dCkModeS).

Consequent actions: None.

Defect correlations:

cCkModeS $\leftarrow$ dCkModeS

Performance monitoring: None.

8.3.2.2 SD-t Layer to NS-p layer adaptation sink function (SD-t/NS-p_A_Sk)

Symbol:

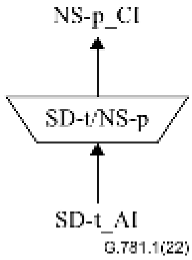

Figure 8-14 – SD-t/NS-p_A_Sk symbol

Interfaces:

Table 8-13 – SD-t/NS-p_A_Sk input and output signals

Input(s)	Output(s)
SD-t_AI_E_{rbest} If the port state is SLAVE, including: SD-t_AI_TS	NS-p_CI_E_{rbest} If the port state is SLAVE, including: NS-p_CI_TS

Processes:

This function connects input with output only. Currently, no processes are defined within this function.

Defects: None.

NOTE – PTSF is for further study.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

8.3.3 SD-t layer to TRef adaptation source function (SD-t/TRef_A_So)

Symbol:

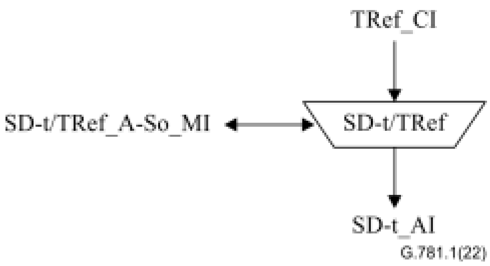

Figure 8-15 – SD-t/TRef_A_So symbol

Interfaces:

Table 8-14 – SD-t/TRef_A_So input and output signals

Input(s)	Output(s)
TRef_CI_TM TRef_CI_Status SD-t/TRef_A_So_MI_TRefOperation	SD-t_AI_TM SD-t_AI_Status SD-t/TRef_A_So_MI_TRefMode SD-t/TRef_A_So_MI_cTRefAlarm

Processes:

This function receives and processes the time reference signal and provides the synchronized time (TM) and the reference status to the SD-t_TT_So trail termination function. This function generates a system clock as defined by the PRTC function of [ITU-T G.8272] or the enhanced primary reference time clock (ePRTC) function of [ITU-T G.8272.1].

This function supports the operations on the time reference:

– Normal operation, working in the locked, warm-up, holdover or free-run mode depending on the input signals.
– Switching operation among the reference time signals (e.g., GPS, BeiDou, Galileo, GLONASS signal).

These operations are activated by the user management input (TRefOperation) while modes are automatically activated by the status of the input signals.

Defects:

If the function cannot receive the time reference signal correctly, this function will detect a time reference alarm (TRefAlarm).

Consequent actions: None.

Defect correlations:

cTRefAlarm ← dTRefAlarm

Performance monitoring: For further study~~FS~~.

8.3.4 SD-t layer to application clock (AppCk) adaptation sink function (SD-t/AppCk_A_Sk)

Symbol:

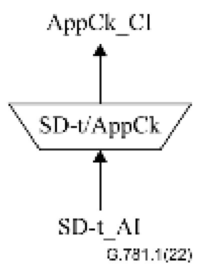

Figure 8-16 – SD-t/AppCk_A_Sk symbol

Interfaces:

Table 8-15 – SD-t/AppCk_A_Sk input and output signals

Input(s)	Output(s)
SD-t_AI_TS	AppCk_CI_TS

The member SD-t_AI_TS is the timing information of a 1PPS+ToD port, including:

a) Time field of the time event message received by the 1PPS+ToD port; and

b) the local timeStamp generated by the port when the time event message is received.

Processes:

This function performs the information translation from the SD-t layer to the application clock layer.

The member AppCk_CI_TS is implementation specific.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

9 Transport layer to SD-p layer atomic functions

9.1 ETH to SD-p adaptation functions

9.1.1 ETH to SD-p adaptation source function (ETH/SD-p_A_So)

Symbol:

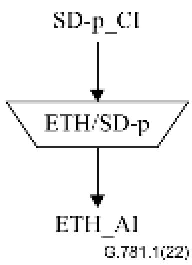

Figure 9-1 – ETH/SD-p_A_So symbol

Interfaces:

Table 9-1 – ETH/SD-p_A_So input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_TM SD-p_CI_portState	ETH_AI_D

Processes:

This function receives the transport-independent information from the SD-p_C function. This function processes the PTP messages compliant with [ITU-T G.8275.1] and [ITU-T G.8275.2].

For the transmission of PTP messages, the PTP messages shall be encapsulated with Ethernet mapping specified by [ITU-T G.8275.1] and IP mapping specified by [ITU-T G.8275.2].

When a sync message is sent at a MASTER port, this function shall generate a timestamp according to the [ITU-T G.8275.1] and [ITU-T G.8275.2], and the timestamp shall be inserted into the sync or a Follow_Up message.

When a Delay_Req message is received at a MASTER port, this function shall generate a timestamp according to [ITU-T G.8275.1] and [ITU-T G.8275.2], and the timestamp is inserted into the corresponding Delay_Resp message.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

9.1.2 ETH to SD-p adaptation sink function (ETH/SD-p_A_Sk)

Symbol:

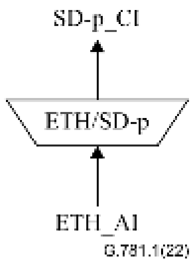

Figure 9-2 – ETH/SD-p_A_Sk symbol

Interfaces:

Table 9-2 – ETH/SD-p_A_Sk input and output signals

Input(s)	Output(s)
ETH_AI_D	SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_LOPTP If the port state is SLAVE, including: SD-p_CI_TS

Processes:

This function processes the PTP messages compliant with [ITU-T G.8275.1] and [ITU-T G.8275.2].

For the transmission of PTP messages, the PTP messages shall be encapsulated with Ethernet mapping specified by [ITU-T G.8275.1] and IP mapping specified by [ITU-T G.8275.2].

When an Announce message is received, the fields of the Announce message should be outputted via SD-p_CI_AnnounceFields.

When a Sync message is received at a SLAVE port or a Delay_Req message is sent at a SLAVE port, this function shall generate a timestamp.

If the port state is SLAVE, the transport-independent information provided to the SD-p_C function shall include the timestamp information.

Defects:

dLOPTP: If no valid PTP messages are received during a time, a loss of PTP (LOPTP) defect is generated. The method of detecting the valid PTP messages shall be consistent with the announceReceiptTimeout event and the PTSF function of [ITU-T G.8275.1] and [ITU-T G.8275.2].

Consequent actions: None.

Defect correlations:

cLOPTP ← dLOPTP

Performance monitoring: For further study.

9.2 OTUk to SD-p adaptation functions

9.2.1 OTUk to SD-p adaptation source function (OTUk/SD-p_A_So)

Symbol:

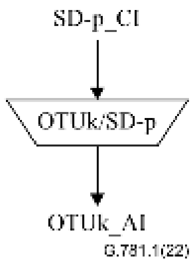

Figure 9-3 – OTUk/SD-p_A_So symbol

Interfaces:

Table 9-3 – OTUk/SD-p_A_So input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_TM SD-p_CI_portState	OTUk_AI_D

Processes:

This function receives transport-independent information from the SD-p_C function. This function processes the PTP messages compliant with [ITU-T G.8275.1].

For the transmission of PTP messages, the PTP messages shall be encapsulated as specified in Annex H of [ITU-T G.8275.1].

When a Sync message is sent at a MASTER port, this function shall generate timestamp according to Annex H of [ITU-T G.8275.1], and the timestamp shall be inserted into the sync or Follow_Up message.

When a Delay_Req message is received at a MASTER port, this function shall generate a timestamp according to Annex H of [ITU-T G.8275.1], and the timestamp is inserted into the corresponding Delay_Resp message.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

9.2.2 OTUk to SD-p adaptation sink function (OTUk/SD-p_A_Sk)

Symbol:

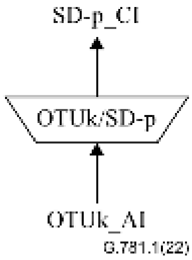

Figure 9-4 – OTUk/SD-p_A_Sk symbol

Interfaces:

Table 9-4 – OTUk/SD-p_A_Sk input and output signals

Input(s)	Output(s)
OTUk_AI_D OTUk_AI_MFS	SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_LOPTP If the port state is SLAVE, including: SD-p_CI_TS

Processes:

This function processes the PTP messages compliant with [ITU-T G.8275.1].

For the transmission of PTP messages, the PTP messages shall be encapsulated as specified in Annex H of [ITU-T G.8275.1].

When an Announce message is received, the fields of the Announce message should be outputted via SD-p_CI_AnnounceFields.

When a Sync message is received at a SLAVE port or a Delay_Req message is sent at a SLAVE port, this function shall generate a timestamp according to Annex H of [ITU-T G.8275.1].

If the port state is SLAVE, the transport-independent information provided to the SD-p_C function shall include the timestamp information.

Defects:

dLOPTP: If no valid PTP messages are received during a time, a loss of PTP (LOPTP) defect is generated. The method of detecting the valid PTP messages shall be consistent with the announceReceiptTimeout event and the PTSF function of [ITU-T G.8275.1].

Consequent actions: None.

Defect correlations:

cLOPTP ← dLOPTP

Performance monitoring: For further study.

9.3 OTSn to SD ~~packet-based sync~~-p adaptation functions

9.3.1 OTSn to SD ~~packet-based sync~~-p adaptation source functions (OTSn/SD-p_A_So)

Symbol:

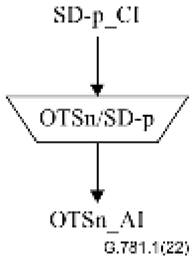

Figure 9-5 – OTSn/SD-p_A_So symbol

Interfaces:

Table 9-5 – OTSn/SD-p_A_So input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_TM SD-p_CI_portState	OTSn_AI_D

Processes:

This function receives transport-independent information from the SD-p_C function. This function processes the PTP messages compliant with [ITU-T G.8275.1].

For the transmission of PTP messages, the PTP messages shall be encapsulated as specified in Annex H of [ITU-T G.8275.1].

When a Sync message is sent at a MASTER port, this function shall generate a timestamp according to Annex H of [ITU-T G.8275.1], and the timestamp shall be inserted into the sync or Follow_Up message.

When a Delay_Req message is received at a MASTER port, this function shall generate timestamp according to Annex H of [ITU-T G.8275.1], and the timestamp is inserted into the corresponding Delay_Resp message.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

9.3.2 OTSn to SD ~~packet-based sync~~-p adaptation source functions (OTSn/SD-p_A_Sk)

Symbol:

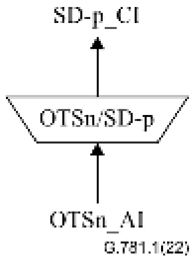

Figure 9-6 – OTSn/SD-p_A_Sk symbol

Interfaces:

Table 9-6 – OTSn/SD-p_A_Sk input and output signals

Input(s)	Output(s)
OTSn_AI_D	SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_LOPTP If the port state is SLAVE, including: SD-p_CI_TS

Processes:

This function processes the PTP messages compliant with [ITU-T G.8275.1].

For the transmission of PTP messages, the PTP messages shall be encapsulated as specified in Annex H of [ITU-T G.8275.1].

When an Announce message is received, the fields of the Announce message should be outputted via SD-p_CI_AnnounceFields.

When a Sync message is received at a SLAVE port or a Delay_Req message is sent at a SLAVE port, this function shall generate timestamp according to Annex H of [ITU-T G.8275.1].

If the port state is SLAVE, the transport-independent information provided to the SD-p_C function shall include the timestamp information.

Defects:

dLOPTP: If no valid PTP messages are received during a time, a loss of PTP (LOPTP) defect is generated. The method of detecting the valid PTP messages shall be consistent with the announceReceiptTimeout event and the PTSF function of [ITU-T G.8275.1].

Consequent actions: None.

Defect correlations:

cLOPTP ← dLOPTP

Performance monitoring: For further study.

9.4 FlexE to SD-p ~~time sync~~ adaptation functions ~~(FlexE/SD-t_A_So and FlexE/SD-t_A_Sk)~~

This function is for further study.

9.5 FlexO to SD-p adaptation functions

9.5.1 FlexO to SD-p adaptation source function (FlexO/SD-p_A_So)

Symbol:

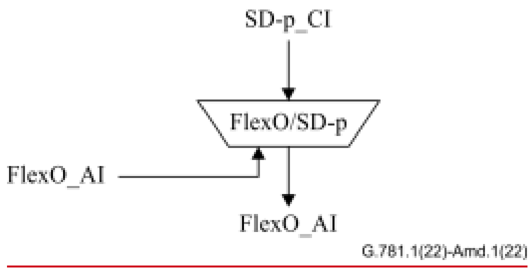

Figure 9-7 – FlexO/SD-p_A_So symbol

Interfaces:

Table 9-7 – FlexO/SD-p_A_So input and output signals

Input(s)	Output(s)
SD-p_CI_AnnounceFields SD-p_CI_TM SD-p_CI_portState FlexO_AI_MFS FlexO_AI_FS	FlexO_AI_D

Processes:

This function receives transport-independent information from the SD-p_C function. This function processes PTP messages compliant with [ITU-T G.8275.1].

For the transmission of PTP messages, the PTP messages shall be encapsulated as specified in Annex H of [ITU-T G.8275.1].

When a Sync message is sent at a MASTER port, this function shall generate a timestamp according to Annex H of [ITU-T G.8275.1], and the timestamp shall be inserted into the Sync or Follow_Up message.

When a Delay_Req message is received at a MASTER port, this function shall generate a timestamp according to Annex H of [ITU-T G.8275.1], and the timestamp is inserted into the corresponding Delay_Resp message.

Defects: None.

Consequent actions: None.

Defect correlations: None.

Performance monitoring: None.

9.5.2 FlexO to SD-p adaptation sink function (FlexO/SD-p_A_Sk)

Symbol:

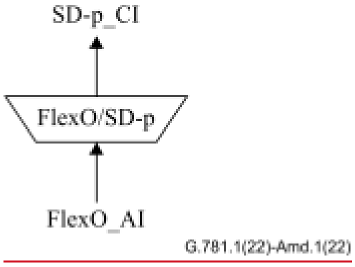

Figure 9-8 – FlexO/SD-p_A_Sk symbol

Interfaces:

Table 9-8 – FlexO/SD-p_A_Sk input and output signals

Input(s)	Output(s)
FlexO_AI_D FlexO_AI_MFS FlexO_AI_FS	SD-p_CI_AnnounceFields SD-p_CI_portState SD-p_CI_LOPTP If the port state is SLAVE, including : SD-p_CI_TS

Processes:

This function processes PTP messages compliant with [ITU-T G.8275.1].

For the transmission of PTP messages, the PTP messages shall be encapsulated as specified in Annex H of [ITU-T G.8275.1].

When an Announce message is received, the fields of the Announce message should be outputted via SD-p_CI_AnnounceFields.

When a Sync message is received at a SLAVE port or a Delay_Req message is sent at a SLAVE port, this function shall generate a timestamp according to Annex H of [ITU-T G.8275.1].

If the port state is SLAVE, the transport-independent information provided to the SD-p_C function shall include the timestamp information.

Defects:

dLOPTP : If no valid PTP messages are received during a time, a loss of PTP (LOPTP) defect is generated. The method of detecting the valid PTP messages shall be consistent with the announceReceiptTimeout event and the PTSF function of [ITU-T G.8275.1].

Consequent actions: None.

Defect correlations:

cLOPTP ← dLOPTP

Performance monitoring: For further study.

Appendix I

Transport layer models for packet-based synchronization information

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

The content of this appendix is for further study.

Appendix II

Examples of packet-based synchronization functionality in the NE

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

The content of this appendix is for further study.

Appendix III

Analysis of message delay times for NEs in packet-based synchronization networks

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

III.1 Introduction

This appendix focuses on PTP and analyses the relation between the Announce message delay times of clause 6.4 and the delay mechanisms within PTP. Three delay times are defined: Non-switching PTP message delay T_{PNSM}, Switching PTP message delay T_{PSM}, and PTP holdover message delay T_{PHM}.

NOTE 1 – In the following subclauses, the impact of the time spent in the acquiring clock state and the tolerance in the Announce message transmission interval have not been considered and are for further study.

NOTE 2 – In this appendix, the notation $a \sim b$ denotes a time interval x such that $a \leq x \leq b$.

III.2 Non-switching PTP message delay T_{PNSM}

When the attribute of the selected time source changes but no switchover to another source is performed, the output Announce message follows this change at the input within a time T_{PNSM} as shown in Figure III.1.

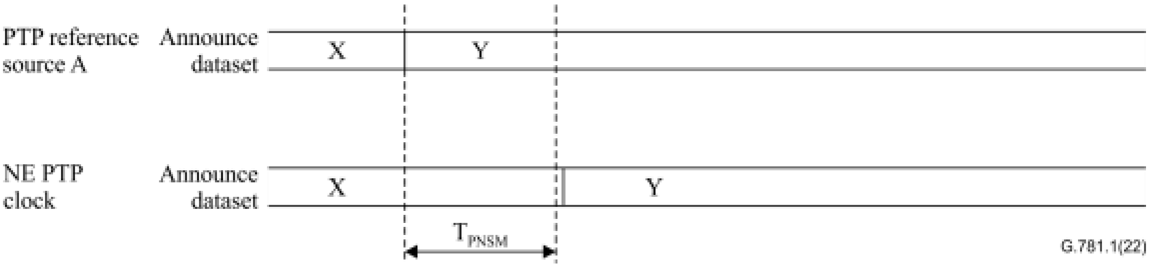

Figure III.1 – Non-switching PTP message delay T_{PNSM}

Non-switching PTP message delay T_{PNSM} = PTP processing time inside node + Announce waiting time before sending

– PTP processing time inside the node is negligible compared with the announceInterval (see clause 7.7.2.2 of [b-IEEE 1588]). T (e.g., 125 ms).

– Announce waiting time before sending is between 0 and T:

- The master's Announce message arrives just at the moment before the slave node is about to send its Announce message to other nodes, then the node's Announce message is sent with a waiting delay of almost 0 (i.e., negligible compared to the message interval T);
- When the master's Announce message arrives just after the slave node device has sent the Announce message, the slave node's next Announce message will wait for a period T.

So:

Non-switching PTP message delay T_{PNSM} = PTP processing time inside node + Announce waiting time before sending

= PTP processing time within 100 μs + Announce waiting time between 0 and T.

≈ Delay time between 0 and T.

III.3 Switching PTP message delay T_{PSM}

This delay applies when a new PTP source is selected due to the loss of the previous time source or the change of time source information. The output Announce message parameters change according to the new PTP source information after a delay T_{PSM}, as shown in Figure III.2.

During the delay time T_{PSM}, the output Announce message will continue to send the information of the previously selected source and maintain the parameters unchanged.

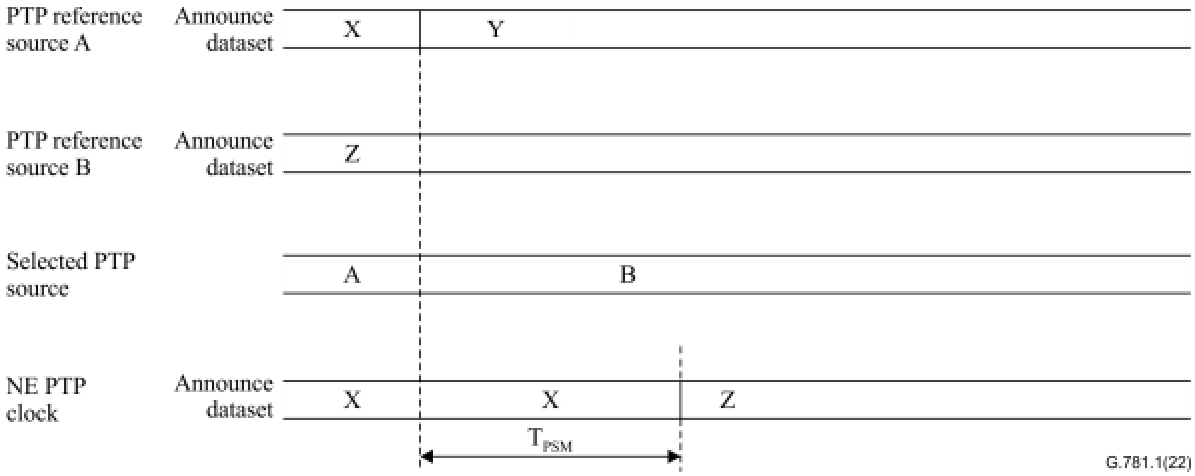

Figure III.2 – Switching PTP message delay T_{PSM}

The switching PTP message delay T_{PSM} can be divided into two situations: (1) the switching is not caused by the Announce message loss, and (2) the switching is caused by the Announce message loss. The delay time is analyzed in these two situations:

(1) The switching PTP message delay T_{PSM} is not caused by the loss of Announce message.

Switching PTP message delay T_{PSM} = (FOREIGN_MASTER_TIME_WINDOW interval) (required in some situations) + PTP processing time inside node + announce waiting time before sending + (qualificationTimeoutInterval from premaster to master state) which is required in some situations,

where FOREIGN_MASTER_TIME_WINDOW interval (see clause 9.3.2.5 of [b-IEEE 1588]) is equal to FOREIGN_MASTER_TIME_WINDOW multiplied by the announceInterval:

– The processing of foreign master information is defined in clauses 9.3.2.4.4 of [b-IEEE 1588-2008] and 9.3.2.4.5 of [b-IEEE 1588-2019]. "The values of these two attributes determine the criteria for accepting an Announce message from a previously silent master clock for consideration in the operation of the best master clock algorithm."

  In normal cases, 2 Announce messages will be received between T and 2·T. So FOREIGN_MASTER_TIME_WINDOW interval is (1~2)·T.

– PTP processing time inside node is negligible compared with the announceInterval T (e.g., 125 ms).

– Announce waiting time before sending is between 0 and T.

– qualificationTimeoutInterval from PRE_MASTER to MASTER state is defined in clauses 9.2.6.10 of [b-IEEE 1588-2008] and 9.2.6.11 of [b-IEEE 1588-2019].

The qualificationTimeoutInterval should be N times T, where:

a) If the recommended state = MASTER event is based on decision points M1 or M2 of Figure 26 of [b-IEEE 1588], N shall be 0.

b) If the recommended state = MASTER event was based on decision point M3 of Figure 26 of [b-IEEE 1588], N shall be the value incremented by 1 (one) of the currentDS.stepsRemoved field.

So:

Switching PTP message delay T_{TSM} = (FOREIGN_MASTER_TIME_WINDOW interval) (required in some situations) + PTP processing time inside node + announce waiting time before sending + (qualificationTimeoutInterval from premaster to master state) which is required in some situations:

= (1~2)·T(required in some situations) + PTP processing time within 100 μs + (0~1)·T + N*T(required in some situations).

In the worst case, switching PTP message delay T_{TSM} = (N+3)·T.

(2) The switching PTP message delay T_{TSM} caused by the loss of Announce message.

Switching PTP message delay T_{TSM} = Announce_Receipt_timeout + (FOREIGN_MASTER_TIME_WINDOW interval) (required in some situations) + PTP processing time inside node + announce waiting time before sending

– Announce_Receipt_timeout is defined in clauses 9.2.6.11 of [b-IEEE 1588-2008] and 9.2.6.12 of [b-IEEE 1588-2019], and it is decided by the value of portDS.announceReceiptTimeout, e.g., 3.
– The processing of foreign master information is defined in clauses 9.3.2.4.4 of [b-IEEE 1588-2008] and 9.3.2.4.5 of [b-IEEE 1588-2019].

  FOREIGN_MASTER_TIME_WINDOW interval is (1~2)·T (see description in (1) above).
– PTP processing time inside node is negligible compared with the message interval T (e.g., 125 ms).
– Announce waiting time before sending is between 0 and T.
– According to Figure 23 of [b-IEEE 1588-2008] and Figure 30 of [b-IEEE 1588-2019], there is no PRE_MASTER state in the case of the loss of the Announce message, so the qualificationTimeoutInterval from PRE_MASTER to MASTER is zero.

So:

Switching PTP message delay T_{PSM} = Announce_Receipt_timeout + (FOREIGN_MASTER_TIME_WINDOW interval) (required in some situations) + PTP processing time inside node + announce waiting time before sending

= 3·T+ (1~2)·T (required in some situations) + PTP processing time within 100 μs + (0~1)·T.

In the worst case, switching PTP message delay T_{PSM} (caused by the loss of Announce message) is 6·T.

III.4 PTP Holdover message delay T_{PHM}

When a clock (T-GM or T-BC) loses its reference because of loss of the input reference signal or due to other reasons, the clock goes into PTP holdover and sends the output Announce message with new values for some parameters after a delay T_{PHM}, as shown in Figure III.3.

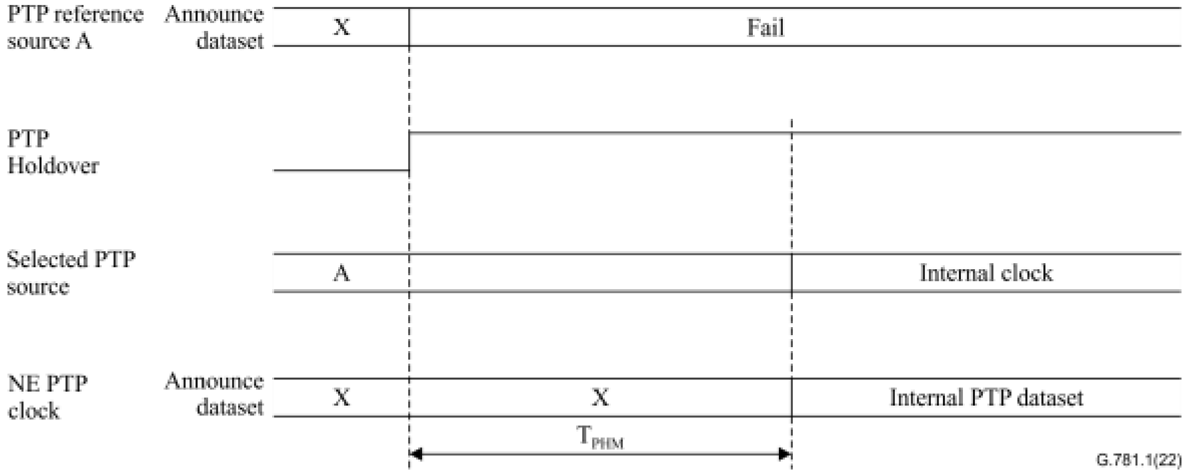

Figure III.3 – PTP Holdover message delay T_{PHM}

If the holdover is caused by the degradation of the input source:

PTP Holdover message delay T_{PHM} = Non-switching PTP message delay T_{PNSM} = (0~1)T

If the holdover is caused by the loss of the input Announce message:

PTP Holdover message delay T_{PHM} = Announce_Receipt_timeout + PTP processing time inside node + Announce waiting time before sending

= 3·T+ (0~1)·T = (3~4)·T.

Bibliography

[b-ITU-T G.8271] Recommendation ITU-T G.8271/Y.1366 (2020), *Time and phase synchronization aspects of telecommunication networks*.

[b-IEEE 1588] Either [b-IEEE 1588-2008] or [b-IEEE 1588-2019] depending on the specific implementation.

[b-IEEE 1588-2008] IEEE 1588-2008, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*. https://ieeexplore.ieee.org/document/4579760

[b-IEEE 1588-2019] IEEE 1588-2019, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*. https://ieeexplore.ieee.org/document/9120376

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Published in Switzerland
Geneva, 2023