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

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

Synchronization layer functions for packet- based synchronization

Recommendation ITU-T G.781.1

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DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
General	G.700–G.709
Coding of voice and audio signals	G.710–G.729
Principal characteristics of primary multiplex equipment	G.730–G.739
Principal characteristics of second order multiplex equipment	G.740–G.749
Principal characteristics of higher order multiplex equipment	G.750–G.759
Principal characteristics of transcoder and digital multiplication equipment	G.760–G.769
Operations, administration and maintenance features of transmission equipment	G.770–G.779
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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
ACCESS NETWORKS	G.9000–G.9999

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Recommendation ITU-T G.781.1

Synchronization layer functions for packet-based synchronization

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).

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Table of Contents

		Page
1	Scope	1
2	References.....	1
3	Definitions	2
	3.1 Terms defined elsewhere	2
	3.2 Terms defined in this Recommendation.....	2
4	Abbreviations and acronyms	2
5	Conventions	3
6	Packet-based synchronization functional model and general principles	3
	6.1 Packet-based synchronization functional model	3
	6.2 Synchronization interfaces	5
	6.3 Automatic reference selection process (alternate BMCA).....	5
	6.4 PTP Announce message delay times for NEs	6
	6.5 Overview of the processes performed within the atomic functions	6
7	Network synchronization layer atomic functions	7
	7.1 NS-p connection function (NS-p_C)	7
8	Synchronization distribution layer atomic functions.....	8
	8.1 SD-p connection function (SD-p_C).....	9
	8.2 Trail termination (TT) functions	11
	8.3 Adaptation functions	16
9	Transport layer to SD-p layer atomic functions	23
	9.1 ETH to SD-p adaptation functions	23
	9.2 OTUk to SD-p adaptation functions.....	25
	9.3 OTSn to SD packet-based sync adaptation functions.....	27
	9.4 FlexE to SD time sync adaptation functions (FlexE/SD-t_A_So and FlexE/SD-t_A_Sk)	28
	Appendix I – Transport layer models for packet-based synchronization information	29
	Appendix II – Examples of packet-based synchronization functionality in the NE	30
	Appendix III – Analysis of message delay times for NEs in packet-based synchronization networks.....	31
	III.1 Introduction	31
	III.2 Non-switching PTP message delay TPNSM.....	31
	III.3 Switching PTP message delay TPSM	32
	III.4 PTP Holdover message delay TPHM.....	33
	Bibliography.....	35

Recommendation ITU-T G.781.1

Synchronization layer functions for packet-based synchronization

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), *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), *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), *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 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
GFP-F	Frame-mapped Generic Framing Procedure
GNSS	Global Navigation Satellite System
MI	Management Information
NE	Network Element
NS-p	Packet-based Network Synchronization
OSC	Optical Supervisory Channel
OTN	Optical Transport Network
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
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

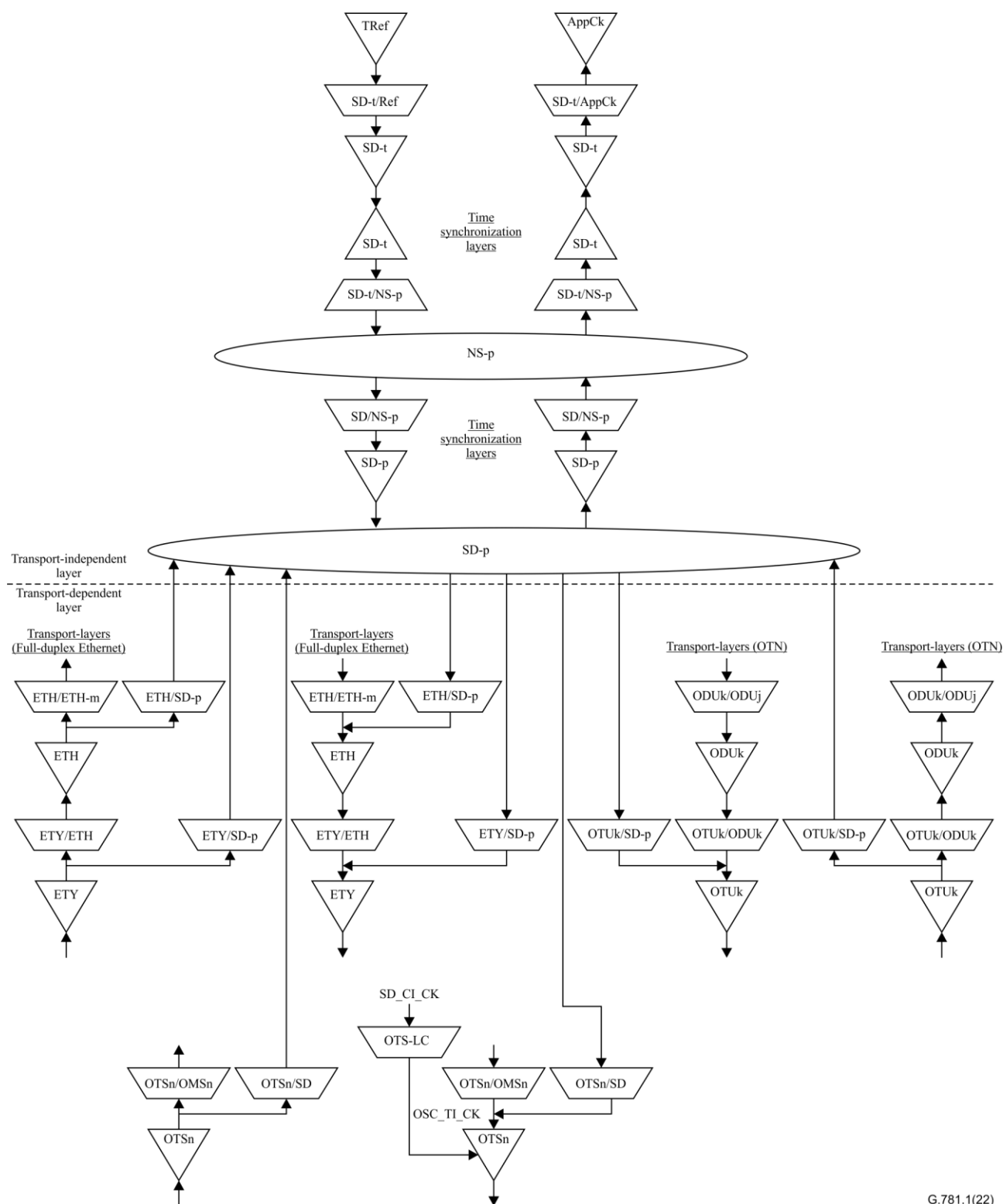
6.1 Packet-based synchronization functional model

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.



G.781.1(22)

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

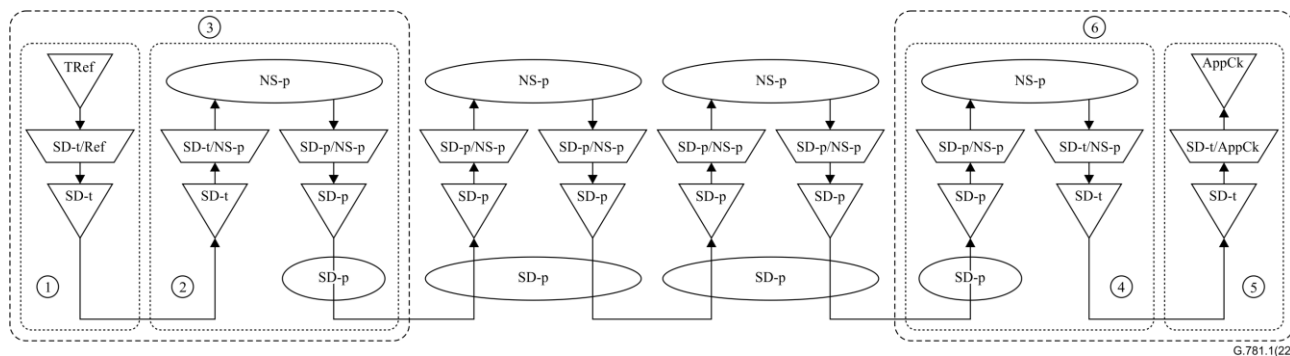


Figure 6-2 – Example of series of packet-based synchronization distribution network connections transporting PRTC-quality timing reference information

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 $E_{r\text{best}}$, 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 $E_{r\text{best}}$ is associated with the external phase/time input. The values are assigned to the virtual $E_{r\text{best}}$ 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, ODUk, or OSC.	

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).

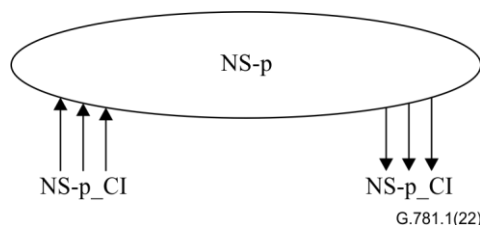


Figure 7-1 – Network synchronization PTP layer atomic functions

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:

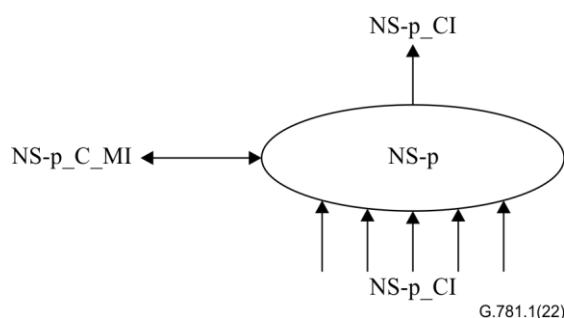


Figure 7-2 – NS-p_C symbol

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_{rbest} (the best data set of all E_{rbest}) and the NS-p_CI_D₀ (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

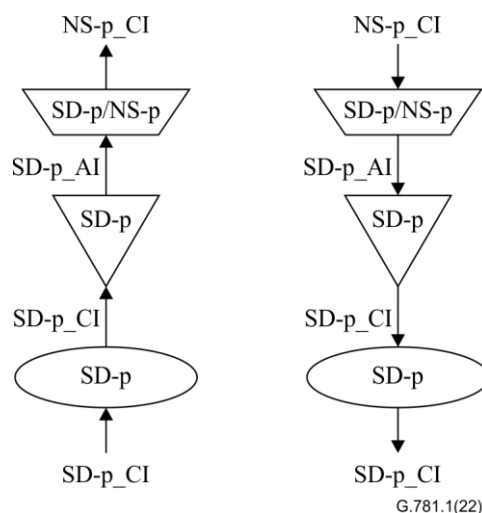


Figure 8-1 – Synchronization distribution layer atomic functions

SD layer CP

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