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Data over Transport – Generic aspects – Transport network control aspects

Management requirement and information model for synchronization

Recommendation ITU-T G.7721

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Recommendation ITU-T G.7721

Management requirement and information model for synchronization

Summary

Recommendation ITU-T G.7721 provides the management requirements and a protocol-neutral management information model for managing network elements and network of synchronization.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.7721	2018-11-29	15	11.1002/1000/13789

Keywords

Information model, management, protocol-neutral, synchronization, unified modelling language (UML).

* 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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1 Scope

This Recommendation will specify the management requirements and information model for managing a synchronization network and equipment based on the synchronization architecture and equipment defined in ITU-T Recommendations. The management information model will be described using an extension to the model artefacts defined in [ITU-T G.7711]. The extensions enable synchronization networks to be managed using the same patterns found in [ITU-T G.7711].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.781] Recommendation ITU-T G.781 (2017), *Synchronization layer functions.*

[ITU-T G.798] Recommendation ITU-T G.798 (2017), *Characteristics of optical transport network hierarchy equipment functional blocks.*

[ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks*.

[ITU-T G.874.1] Recommendation ITU-T G.874.1 (2016), *Optical transport network: Protocol-neutral management information model for the network element view*.

[ITU-T G.7710] Recommendation ITU-T G.7710/Y.1701 (2012), *Common equipment management function requirements*.

[ITU-T G.7711] Recommendation ITU-T G.7711/Y.1702 (2018), *Generic protocol-neutral management Information Model for Transport Resources.*

[ITU-T G.8021] Recommendation ITU-T G.8021/Y.1341 (2016), *Characteristics of Ethernet transport network equipment functional blocks.*

[ITU-T G.8052] Recommendation ITU-T G.8052/Y.1346 (2018), *Protocol-neutral management information model for the Ethernet transport capable network element.*

[ITU-T G.8152] Recommendation ITU-T G.8152/Y.1375 (2018), *Protocol-neutral management information model for the MPLS-TP network element.*

[ITU-T G.8260] Recommendation ITU-T G.8260 (2015), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8264] Recommendation ITU-T G.8264/Y.1364 (2017), *Distribution of timing information through packet networks.*

[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 (2017), *Time and phase synchronization aspects of telecommunication networks.*

[ITU-T G.8275.1] Recommendation ITU-T G.8275.1 (2016), *Precision time protocol telecom profile for phase/time synchronization with full timing support from.*

[ITU-T G.8275.2] Recommendation ITU-T G.8275.2/Y.1369.1 (2016), *Precision time protocol telecom profile for time/phase synchronization with partial timing support from the network.*

[ITU-T P.562] Recommendation ITU-T P.562 (2004), *Analysis and interpretation of INMD voice-service measurements.*

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 STM-N [ITU-T G.8021 (2010)].

3.1.2 E1 [ITU-T P.562].

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:

1PPS One Pulse Per Second

BC Boundary Clock

BMCA Best Master Clock Algorithm

CASC Configuration and Switch Control

CES Circuit Emulation Services

CLK Clock

DNU Do Not Use

FC Forwarding Construct

FCAPS Fault, Configuration, Accounting, Performance and Security

FD Forwarding Domain

GE Gigabit Ethernet

ID Identification

LTP Logical Termination Point

MAC Media Access Control

NE Network Element

OC Ordinary Clock

OSS Operations Support System

P2P Point To Point

PRC Primary Reference Clock

PTP Precision Time Protocol

SASE Standalone Synchronization Equipment

SDN Software Defined Network

SSM Synchronization Status Message

SSU Synchronization Supply Unit

SyncE Synchronous Ethernet

SyncO Synchronous Optical Transport Network

TC Transparent Clock

ToD Time of Day

UDP User Datagram Protocol

UML Unified Modelling Language

UNK Unknown

VLAN Virtual Local Area Network

WTR Wait To Restore

5 Conventions

5.1 Information modelling conventions

5.1.1 UML modelling conventions

See [ITU-T G.7711] clause 5.1.

5.1.2 Model Artefact Lifecycle Stereotypes conventions

See [ITU-T G.7711] clause 5.2.

5.1.3 Forwarding entity terminology conventions

See [ITU-T G.7711] clause 5.3.

5.1.4 Conditional package conventions

See [ITU-T G.7711] clause 5.4.

5.1.5 Pictorial diagram conventions

See [ITU-T G.7711] clause 5.5.

6 Management requirements for synchronization

The management requirements for synchronization in this Recommendation are common to multiple transport technologies. The management of the synchronization network is based upon the traditional OSS or SDN controller.

The management of the equipment synchronization function includes the FCAPS functions (fault, configuration, accounting, performance and security) for synchronization. Each function includes the management of frequency and time respectively.

The common equipment management requirements are defined in [ITU-T G.7710].

6.1 Configuration management

Configuration management provides functions to collect data from and provide data to network elements (NEs). Configuration management for synchronization supports (1) planning and set up of the sync path based on the sync network topology and avoiding clock loop in the sync path; (2) to set up at least two paths for each device to avoid the breakdown of clock synchronization due to the failure of a link or device; (3) reconfiguration of the sync path if the sync network topology changes; (4) configuration of the frequency sync and time/phase sync parameters for transport equipment.

6.1.1 Configuration management of frequency synchronization

The functions of frequency synchronization of NEs should be configurable and manageable.

1) Configure the priority list of frequency system clock. The clocks below could be selected:
   - external clock (e.g., 2 MHz or 2 Mbit/s);
   - clock extracted from line-side input signals (e.g., STM-N, GE, SyncO);
   - clock extracted from CES services (e.g., E1, STM-N);
   - clock recovered from PTP messages;
   - internal clock (free run or hold over).
2) Configure the type of input/output external clock: e.g., 2 MHz or 2 Mbit/s.
3) Enable/disable synchronization status messages (SSM) for the NE.
4) Query the status of frequency system clock (locked, free-run, and hold over, etc.).
5) Configure the SSM value of the internal clock of the NE.
6) Extended SSM parameters for GE and SyncO.
7) Configure wait to restore time (WTR).
8) Switch commands for each sync port; lock-out, manual switch and forced switch.
9) Configure whether the clock switches back to previously selected source or not after recovery.
10) Configure whether to take UNK as one of the SSM quality levels or not. If UNK is enabled, its level lies between PRC and SSU_T; otherwise it is taken as 'do not use' (DNU).

The following configuration and management functions of in-band clock ports could be required:

1) Enable/disable synchronization status messages (SSM) for the port.
2) Query current input/output SSM values of the port.
3) Configure to use manual or automatic input/output SSM values.
4) Configure input/output SSM values for the port.

The following configuration and management functions of external clock ports could be required:

1) Enable/disable the port.
2) Configure the type of input/output external clock: 2 MHz or 2 Mbit/s.
3) Configure the source used for the external clock output port. The clocks below could be selected:
   - system clock;
   - clock extracted from line-side input signals (e.g., STM-N, GE).
4) Configure sa-bit bits to carry input and output SSM message.
5) Configure the SSM out-threshold, used to decide whether to send SSM messages or not when the SSM value is lower than the threshold.
6) Query current input/output SSM values of the port.

7) Configure to use manual or automatic input/output SSM values.

8) Configure input/output SSM values for the port.

6.1.2 Configuration management of time synchronization

The function of time synchronization protocols, such as PTP protocol, should be configurable and manageable for NEs:

1) Enable/disable the PTP function of the NE (causes the system clock to enter free run).

2) Query the running mode of the PTP system clock, including tracing and non-tracing.

3) Configure the PTP domain number of the NE.

4) Configure the PTP device type, including boundary clock (BC), transparent clock (TC), TC+BC and ordinary clock (OC).

5) Configure the PTP delay mechanism of the NE, including E2E.

6) Configure the NE to PTP slave only.

7) Query the PTP status dataset of the current tracing source, including grandmasterIdentity, parent ID, priority 1, priority 2, clockClass, accuracy, offsetScaledLogVariance, timesource, stepsRemoved, currentUtcOffset, ptpTimescale, timeTraceable, frequencyTraceable, 1588 protocol version and current absolute time.

8) Configure the PTP status dataset of internal clock of the NE, including CLK ID, priority 1, priority 2, clockClass, accuracy, offsetScaledLogVariance, timesource, stepsRemoved, and 1588 protocol version.

The following configuration and management functions of PTP ports could be required:

1) Enable/disable the PTP function of the port.

2) Query the state of the PTP port, including master, slave, passive, initializing, listening, premaster, uncalibrated and faulty.

3) Configure the transmission interval of PTP announce messages.

4) Configure the receipt timeout of PTP announce messages.

5) Configure the transmission interval of PTP sync messages.

6) Configure the transmission interval of PTP delay_req/Pdelay_req messages.

7) Configure the PTP delay mechanism of the port, including E2E.

8) Configure the one-step or two-step mechanism of the port.

9) Configure the asymmetry correction value of the PTP port.

10) Configure the configuration of UDP encapsulation, including source IP address, destination IP address and IPv4/IPv6 protocol.

11) Configure the configuration of MAC encapsulation, including source MAC address, destination MAC address and VLAN configuration.

The following configuration and management functions of 1PPS+TOD time ports could be required:

1) Configure the status of the external time port: input or output port.

2) Configure the status dataset of the external time port, including grandmasterIdentity, priority 1, priority 2, clockClass, accuracy, offsetScaledLogVariance, timesource, stepsRemoved, and currentUtcOffset.

3) Configure the delay compensation value of the external time port.

6.2 Fault management

Fault management for synchronization supports the detection, isolation and correction of abnormal operation of the synchronization network and elements.

Fault management of the physical layer frequency supports the reporting and handling for the following alarms:

– loss of timing inputs (dLTI);
– clock unlock;
– frequency offset source performance degradation;
– SSM level degradation;
– loss of SSM.

Fault management of the packet-based time/frequency synchronization supports the reporting and handling for the following alarms:

– time unlock;
– TOD (or PTP) input degradation;
– time offset/accumulated time offset over the limit;
– loss of PTP message;
– loss of PPS+TOD.

6.3 Performance management

Performance management for synchronization supports evaluating and reporting the synchronization performance of the network or NE.

Performance management of the physical layer frequency supports the handling for the following performance monitoring function:

– frequency offset monitoring.

Performance management of the packet-based time/frequency synchronization supports the handling for the following performance monitoring function:

– PTP time offset/accumulated time offset monitoring;
– time error measurement at a passive port.

7 Synchronization management model

7.1 Synchronization model overview

This clause provides an initial sketch of the information model for synchronization management.

7.1.1 Management view of the synchronization network

An NE that supports a slave clock function (i.e., a local frequency or time reference) will terminate several interfaces that support trails and links in one or more layer networks. These links may support user traffic, synchronization information or both.

The synchronization distribution trails will be present within some of these interfaces. The selection of the synchronization input and the distribution of the output of the slave clock are independent. For example, at the edge of a network an NE may have two links that support an incoming synchronization signal but the output of the slave clock would not be distributed to other NEs. It is more convenient to describe the functional model for synchronization using unidirectional constructs.

7.1.1.1 Simplified equipment model

Figure 7-1 and Figure 7-2 below show a simplified equipment model for a network element that has an internal clock. The connection to an external clock (e.g., a boundary clock for PTP or standalone synchronization equipment (SASE) for frequency synchronization) is for further study. The management abstractions required to represent an external clock are provided later in this document.

The simplified equipment model for time synchronization using PTP is shown in Figure 7-1 below.

The figures include numbers that show the flow of a synchronization signal from the input of the NE to the output of the NE.

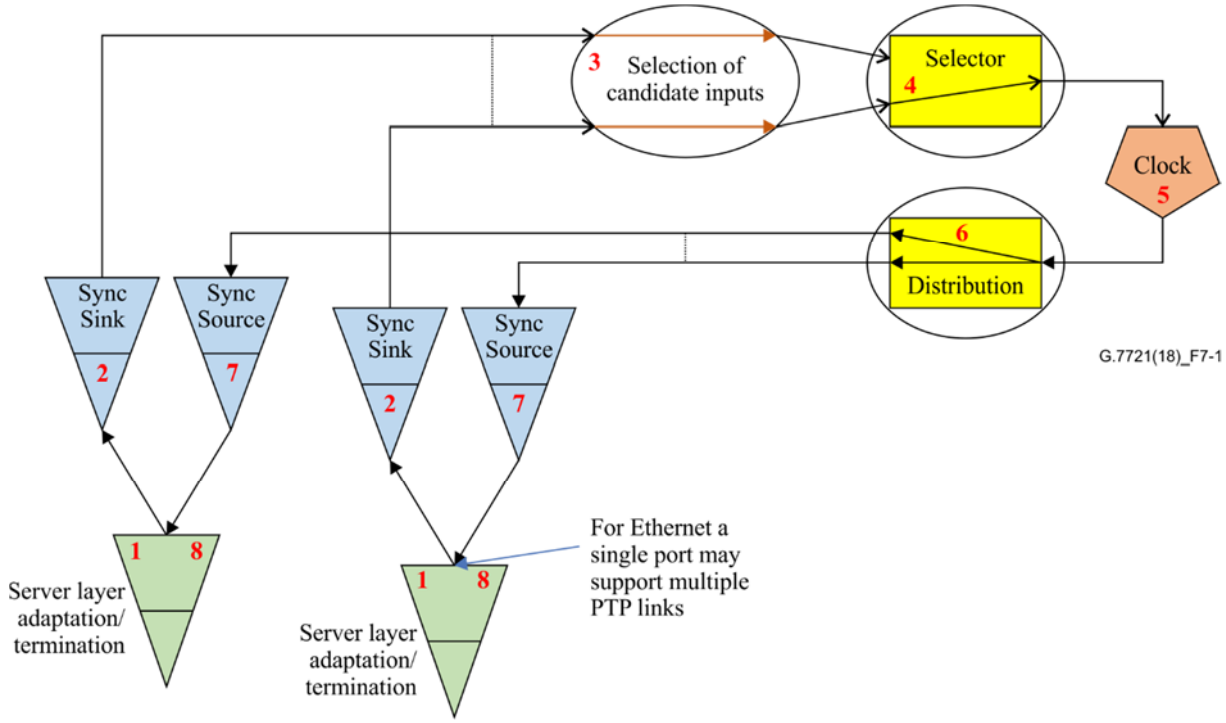


Figure 7-1 – Simplified sync equipment model of a transport NE using PTP

The processes associated with the functions in Figure 7-1 are outlined below. Note that steps 4-8 also apply to the case of physical layer sync using SSM described below.

1) Terminate the server layer.
   a) The specification is provided in Recommendations under the responsibility of ITU-T Study Group 15 Q10 (e.g., [ITU-T G.8021]) or Q11 (e.g., [ITU-T G.798]).
2) The synchronization sink function extracts the synchronization information[1] from the sync links (identified by the management plane) as "potential" sync inputs and forwards it to (3).
   a) Report the content of the status of the synchronization trail including the contents of the PTP announce messages to management.
3) This selects a subset of the "potential" inputs as candidates to provide the synchronization information to the protection process (4) (i.e., enabling or disabling the associated port). This process is optional and may be null.
   a) Management plane configures this process.

[1] Synchronization information includes: for frequency synchronization, the frequency and synchronization status messages, and for precision time, the time stamp and other contents of the PTP announce messages.

4) Selector

a) Based on the quality of the synchronization inputs (PTP announce messages) and priorities provided by the management plane the selection process selects one of the candidates and forwards it to the clock function (5). Note: in case of PTP the input selection process may use the best master clock algorithm (BMCA).

5) Clock function processes the input sync information (frequency and SSM or time stamp and PTP announce messages) and provides the modified sync information to the sync distribution function (6).

a) If none of the inputs meet the quality defined by the management plane the clock may enter a hold-over or free-run mode. The status of the clock will be reported to the management system.

6) Distribute the synchronization information from the clock to the output ports via (7).

a) The management system must define which outputs are intended to carry the synchronization information.

b) The PTP announce messages sent by the sync source that is bound to the server layer adaptation/termination that is currently used as the sync input to the clock may be different from the PTP announce messages sent by the other sync source.

7) This encodes the synchronization information provided by the clock function to allow it to be carried by the server layer.

8) Terminate the server layer.

a) The specification is provided in Recommendations under the responsibility of Q10 (e.g., [ITU-T G.8021]) or Q11 (e.g., [ITU-T G.798]).

Figure 7-2 below shows the model for frequency synchronization using SSM as described in [ITU-T G.781].

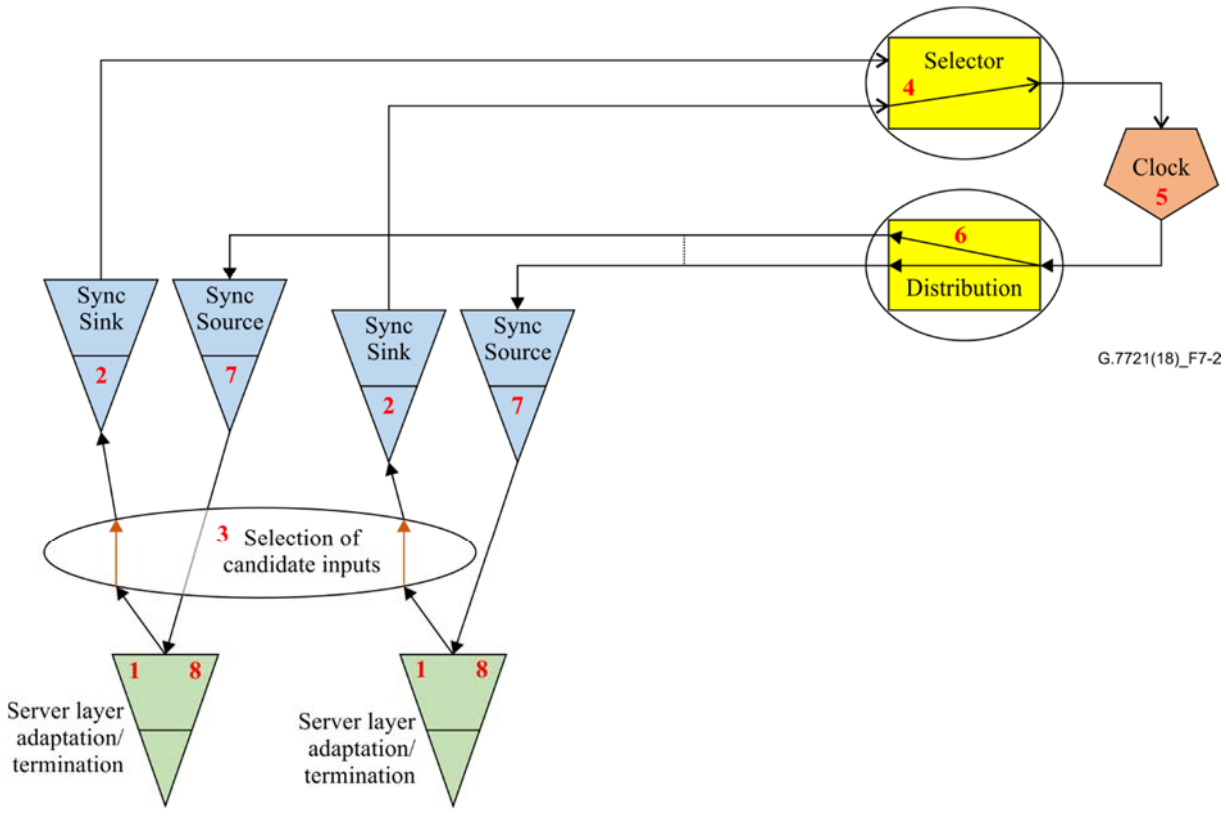


Figure 7-2 – Simplified equipment model of a transport NE that uses physical layer based frequency sync with SSM

NOTE 1 – The candidate selection shown above can select an input from any suitable server layer adaptation/termination function. This is normally preconfigured by management.

The processes associated with the functions in Figure 7-2 are outlined below.

NOTE 2 – The selection of candidate inputs function (3) is between the server layer (1) and sync layer functions (2) and operates only in the input (sink) direction.

1) Terminate the server layer.
   a) This specification is provided in Recommendations under the responsibility of Q10 (e.g., [ITU-T G.8021]) or Q11 (e.g., [ITU-T G.798]).
2) Selects a subset of the "potential" inputs as candidates to provide the synchronization information to the synchronization sink function (2) (this in effect enables or disables a port).
   a) Management plane configures this process.
3) The synchronization sink function extracts the synchronization information[2] from the sync links (identified by the management plane) as "potential" sync inputs and forwards it to (4).
   a) Report the content of the status of the synchronization trail including the contents of the SSM messages to management.

The other functions (4-8) are as described above for the PTP case.

7.1.1.1.1 Optional redundant NE clock

Support of a redundant NE clock is illustrated in Figure 7-3 below.

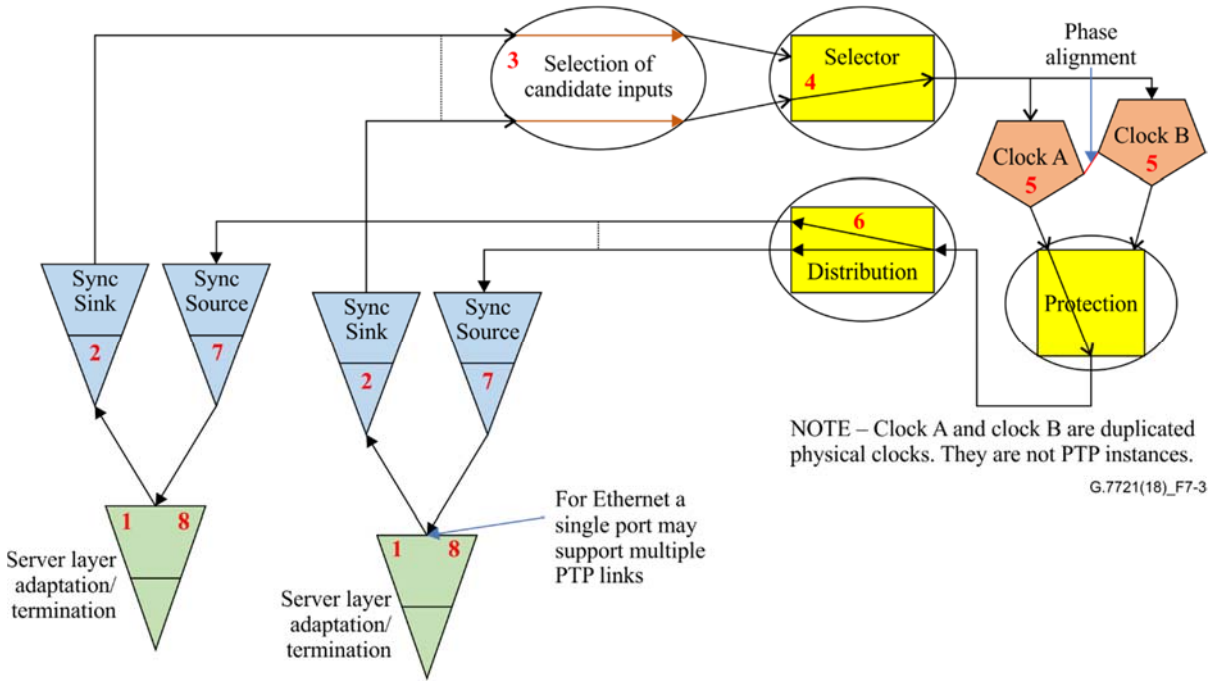


Figure 7-3 – Simplified sync equipment model using PTP with redundant NE clocks

[2] Synchronization information includes: for frequency synchronization the frequency and synchronization status messages, and for precision time the time stamp and PTP messages.

Note that in normal operation one clock is selected as the "master" and this participates in the BCMA algorithm, the other (slave) clock tracks the same input and is phase aligned to the "master" clock. The protection selector at the output of the clock functions is driven by the (internally monitored) status of the NE clocks. This selection process determines the roles of the clocks (master/slave). The assignment of the master/slave roles may be changed as a result of the detection of an equipment failure or by external (management) commands.

Additional redundancy schemes are for further study.

7.1.1.2 Management abstractions

For the purposes of management, the functions (and/or processes) described above will be represented as described below. Note that these are described in terms of instances of the LogicalTerminationPoint (LTP) or ForwardingConstruct (FC) classes from this Recommendation (and [b-ONF TR-512]) or the clock class defined in this Recommendation, which represent the specific synchronization function. These are described in terms of unidirectional instances since this simplifies the description. Normally bidirectional instances will be used.

1) Termination of the server layer

   a) 

   Sink part of a bidirectional server layer LTP instance as defined in [ITU-T G.874.1] (OTN), [ITU-T G.8052] (Ethernet), [ITU-T G.8152] (MPLS-TP).

2) Synchronization sink function

   a) 

   Sink part of a client layer LTP object instance that supports unidirectional Synchronization Sink function[3].

   b) Server layer specific optional packages may be required to allow management of the adaptation/termination processes.

3) Selection of candidate inputs for the Selector process (4)

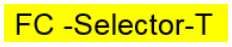
   a) For frequency synchronization

      Creation/removal of the relationship between an instance of the server layer LTP and an instance of the client layer Sync LTP.

   b) For PTP

      Creation/removal of the relationship between an instance of the client layer Sync LTP and an instance of the selector FC (4).

4) Selector process

   a) 

   New object instance unidirectional Sync selection ForwardingConstruct.

5) Clock function

   a) 

   New object instance Clock.

6) Clock distribution

   a) 

   This is modelled indirectly by the creation or removal of the relationship between the Clock and a Sync So LTP.

---

[3] For all of the object instances representing "Sync" separate conditional packages will be defined for frequency and precision time. The objects will be constructed from the base class using composition (as defined in [ITU-T G.7711]).

7) Synchronization source function

a) 

Source part of a client layer LTP object instance that supports a unidirectional sync source function.

b) Server layer specific optional packages may be required to allow management of the adaptation/termination processes.

8) Terminate server layer

a) 

Source part of a bidirectional server layer LTP instance as defined in [ITU-T G.874.1] (OTN), [ITU-T G.8052] (Ethernet), [ITU-T G.8152] (MPLS-TP).

7.1.1.3 Object construction

Object instances of LTP, FC, ForwardingDomain (FD) are used to represent the synchronization functions and are constructed from the base classes using the Spec approach. This aligns with the approach taken in this Recommendation (and [b-ONF TR-512]) and avoids the creation of specialized object classes. A sketch of the relationships for the synchronization LTP instances is provided below in Figure 7-4.

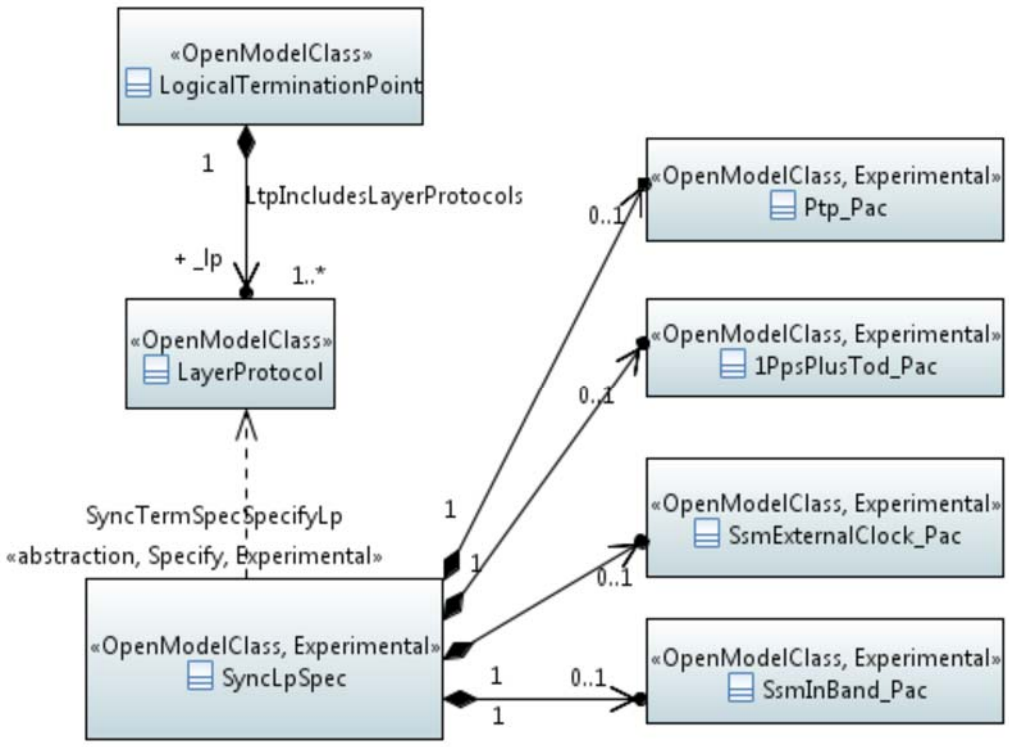


Figure 7-4 – Synchronization LTP construction

The clock function is represented by an instance of Clock object class constructed as shown in Figure 7-5.

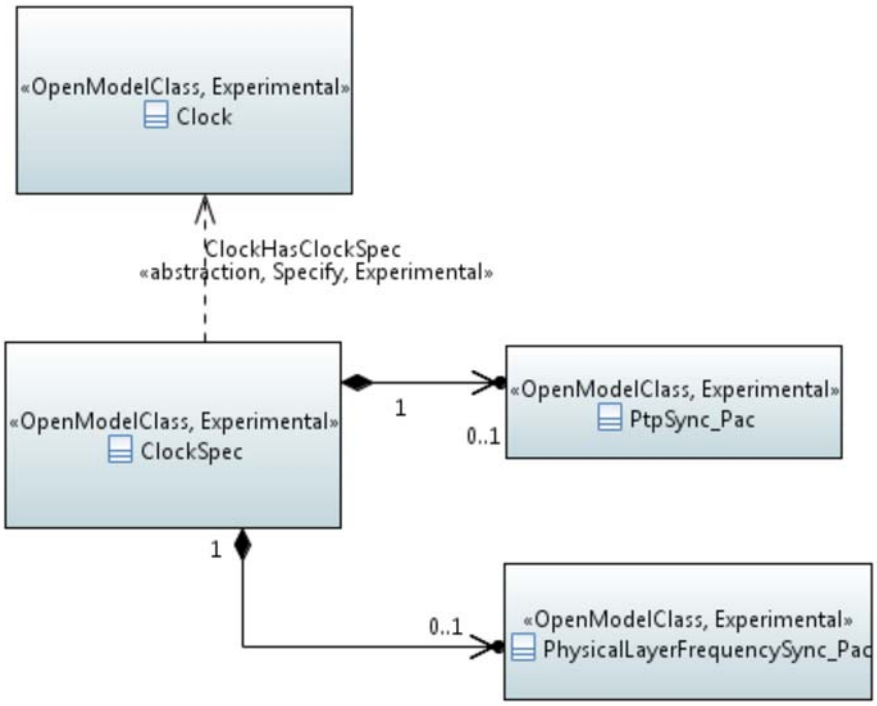


Figure 7-5 – Clock object class construction

The unidirectional synchronization selection FC instance will be based on one of the [ITU-T G.7711] protected point-to-multi-point FCs together with the ConfigurationAndSwitchControl (CASC) from this Recommendation.

7.1.1.4 Synchronization network management domain

7.1.1.4.1 PTP domain model

According to the definitions of PTP domain that are defined in [IEEE 1588] and [ITU-T G.8275.1], the modelling features of the PTP domain can be captured as follows:

1) a logical grouping of clocks;
2) a PTP domain is configured by a PTP profile;
3) an NE may contain multi-PTP instances (clocks) with each instance operating in different PTP domains.

The PTP domain instance example is illustrated in Figure 7-6:

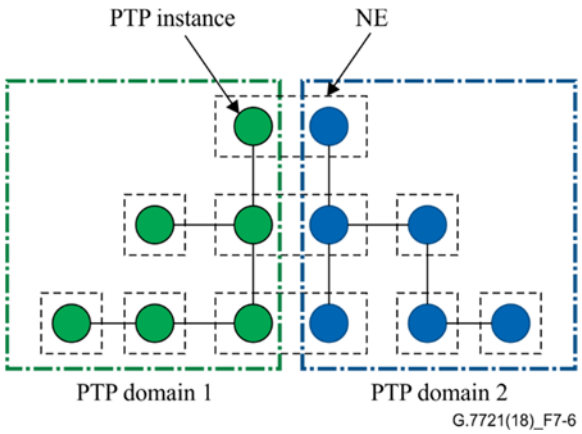


Figure 7-6 – PTP domain instances example

According to the modelling features, the PTP domain can be modelled as ConstraintDomain. The ConstraintDomain should be specified by the attributes of the PTP domain when representing a PTP domain. It should be noted that the ConstraintDomain object class can also be used to represent an NE. The grouping association between ConstraintDomain and Clock is required for the relationship between the NE and Clock and the relationship between the PTP domain and Clock. For the modelling details see clause 7.1.5.3. For the attributes of the PTP domain see the clause 7.2.5.

7.1.2 Mapping of synchronization equipment functions to management artefacts

The following figures illustrate the mapping of the synchronization equipment functions to the management information model artefacts.

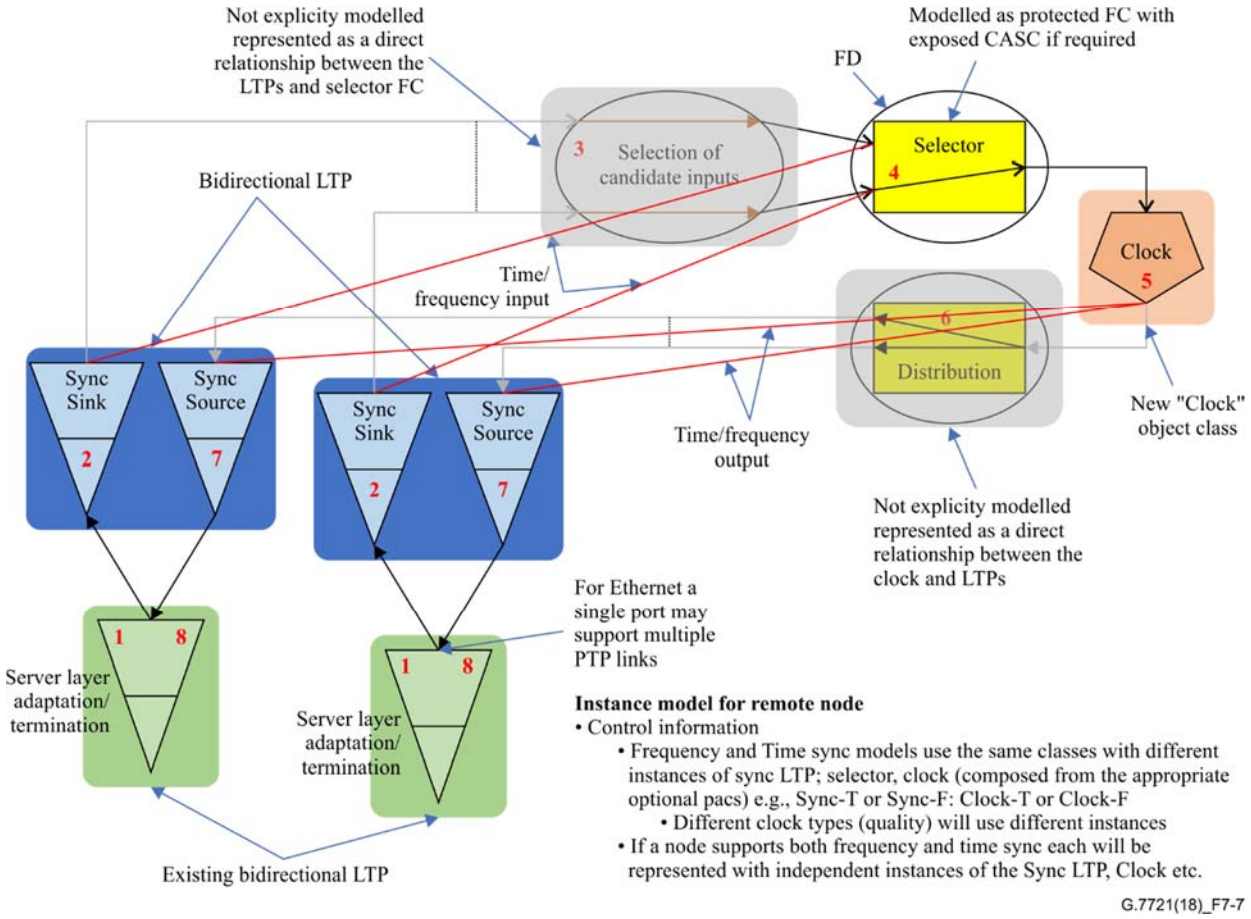


Figure 7-7 – Mapping Figure 7-1: Simplified sync equipment model using PTP to object instances

Different types of clocks or server layers would be modelled using different instances (constructed from using the appropriate optional pacs) of the same object classes.

Figure 7-7 above does not show the control information that is passed between the Sync LTPs, the selector and the clock, this has been added in the figure below; for clarity the configuration and switch control (CASC) has been separated from the selector FC.

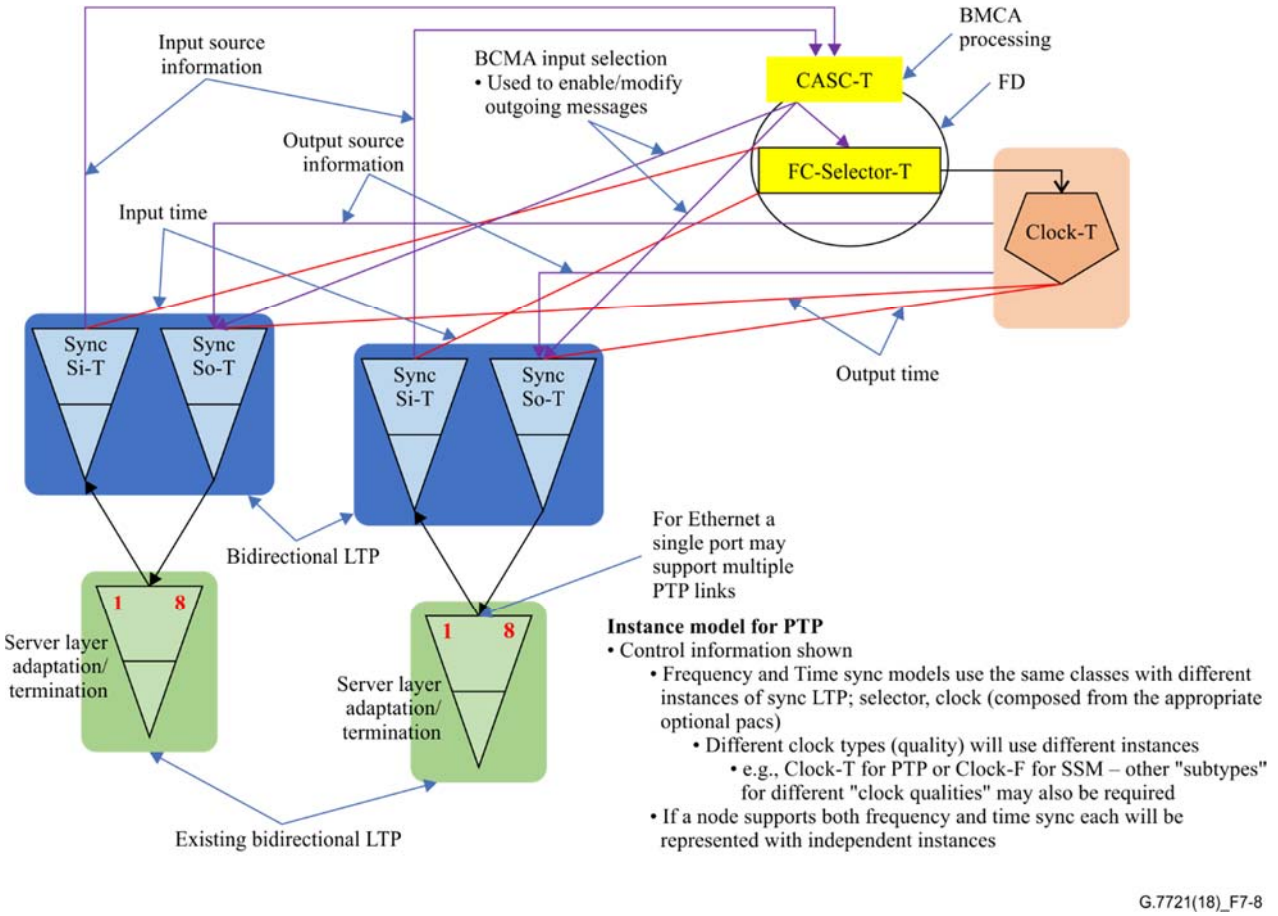


Figure 7-8 – Mapping Figure 7-1: With relationships for control information added

The Sync Si LTP separates the incoming PTP message into "control information" (e.g., source quality, identifier) and "time" information (e.g., time stamp).

The CASC uses the source input information to select the best available input (or instructs the local clock to go into hold-over or free-run mode). The CASC also informs the Sync So LTP which input (if any) has been selected so that the appropriate control messages can be transmitted.

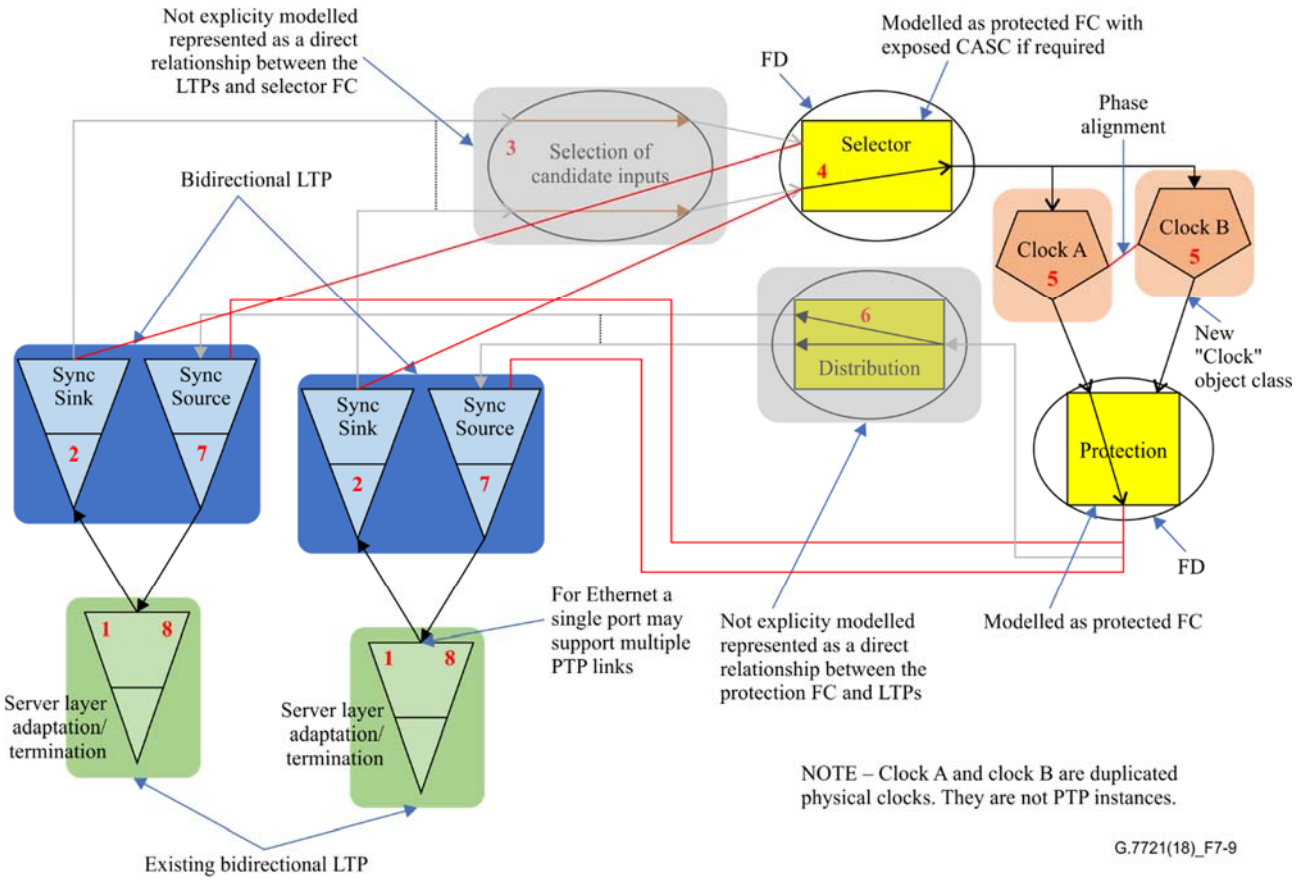


Figure 7-9 – Mapping Figure 7-3: Simplified sync equipment model using PTP with redundant NE clocks to object instances

7.1.2.1 Refactoring management artefacts

The management artefacts could be refactored to reduce the number of object instances in the case where some details are not of interest. An (extreme) example is provided in Figure 7-10 below. In this example the input selection FD/FC, the pair of redundant clocks and the output protection FD/FC are encompassed by a single instance of the clock. This would provide a simplified model but with limited visibility of the details of the implementation.

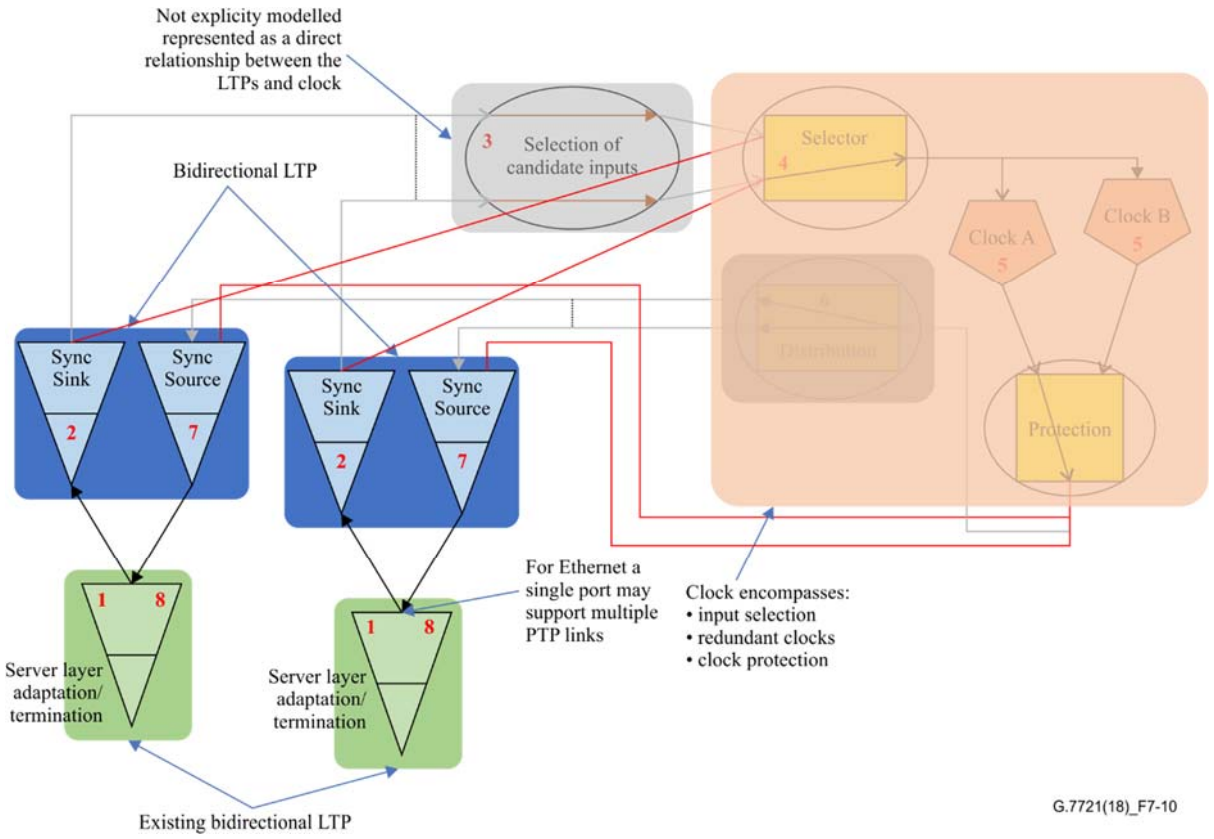


Figure 7-10 – Example of a refactored/simplified view

7.1.3 Example use of the model

An example of the instantiation of the model for an NE with an internal clock is provided below in Figure 7-11.

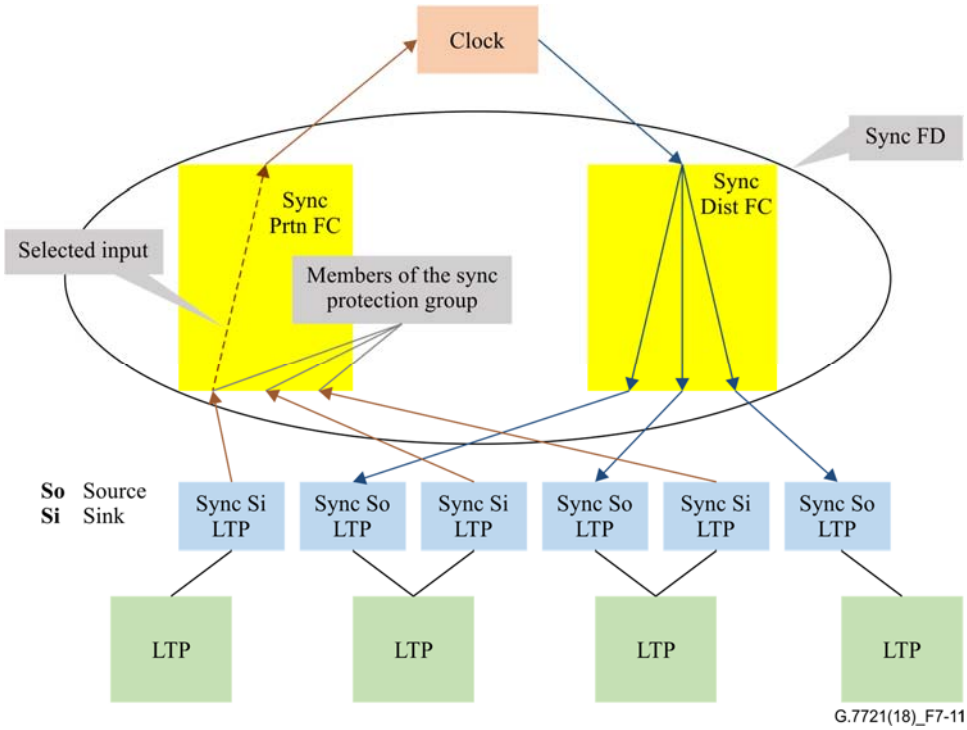


Figure 7-11 – Example of the use of the synchronization management model

NOTES for Figures 7-11 and 7-12:

– Each green LTP is an instance of the LTP class that represents the termination of the server layer.

– Each blue LTP is an instance of the client layer LTP class that represent the sync function.

– The yellow FC is an instance of the FC class that represents the sync selection functions.

– The peach Clock is an instance of the clock class that represents the NE clock function.

– For the purposes of illustrating the signal flow the Sync Si LTP and Sync So LTP are shown as separate instances. However, particularly for PTP, a bidirectional instance of the Sync LTP can be used.

– When detailed management of sync protection is not required the status of the Sync protection FC may be provided by the Clock by including the information on the sync protection (from the Sync protection FC) in the clock. In this case instances representing the sync protection FC and sync FD will not be created.

This set of managed object will be used to manage the (frequency or time) synchronization functions of the network element with an internal clock. Typically the server layer LTPs would also terminate user traffic. Also the NE will normally support additional LTPs and FDs/FCs in multiple layer networks to support the management (termination and/or connectivity) of user traffic.

The rules for the instantiation of the Sync LTP instances depend on the capabilities of the hardware and the policy of the network operator. At least the following options for the behaviours should be supported by the model:

1) Created by management action: The management system explicitly creates (and deletes) the Sync LTP instances.

   a) The management system also creates/breaks the associations between the Sync LTP instances and the Sync FC (for time) instance or server layer LTP instances (for frequency).

2) Auto created: The NE instantiates the Sync LTP instances when sync status messages or PTP announce messages are detected.

   a) The relationship between the Sync LTP instances and the Sync FC (for time) instance or server layer LTP instances (for frequency) is initially "null" and must be configured by the manager.

   b) The relationship between the Sync LTP instances and the Sync FC (for time) instance or server layer LTP instances (for frequency) is automatically created when the Sync LTP instances are created.

      b.1 The Sync protection priority should be set to "low" and may be reconfigured by management or PTP protocol actions.

Note that the same set of managed object classes (with different pacs to reflect the different clock quality and capability) could be used to represent, for example, a boundary clock NE or a stratum 2 clock.

An example of the instantiation of the model of a transport NE connected to a standalone external clock is provided in Figure 7-12.

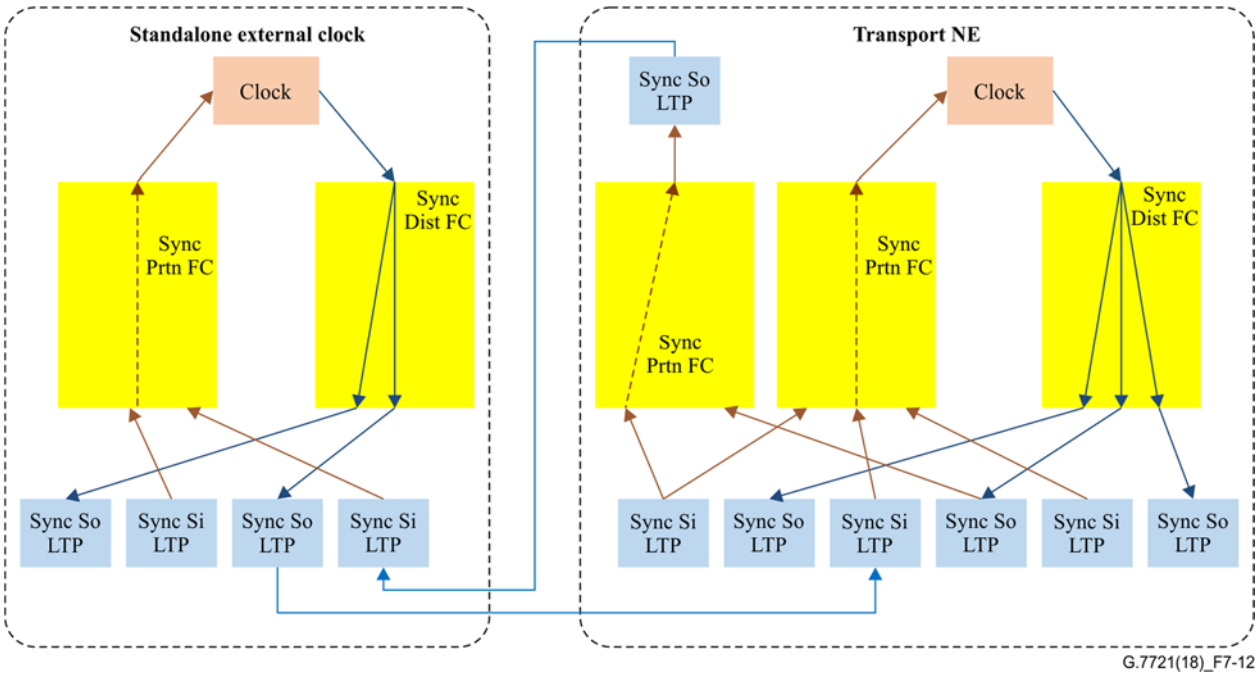


Figure 7-12 – External clock and transport NE

To avoid adding clutter to the figure the server layer LTP instances and the FD instances are not shown in Figure 7-12. The standalone external clock could be a boundary clock (for time) or a stratum 2 clock (for frequency). Other configurations are possible; for example, the output from the transport NE could be provided by the NE clock.

An example of the instantiation of the model for an NE with redundant internal clocks is provided below in Figure 7-13.

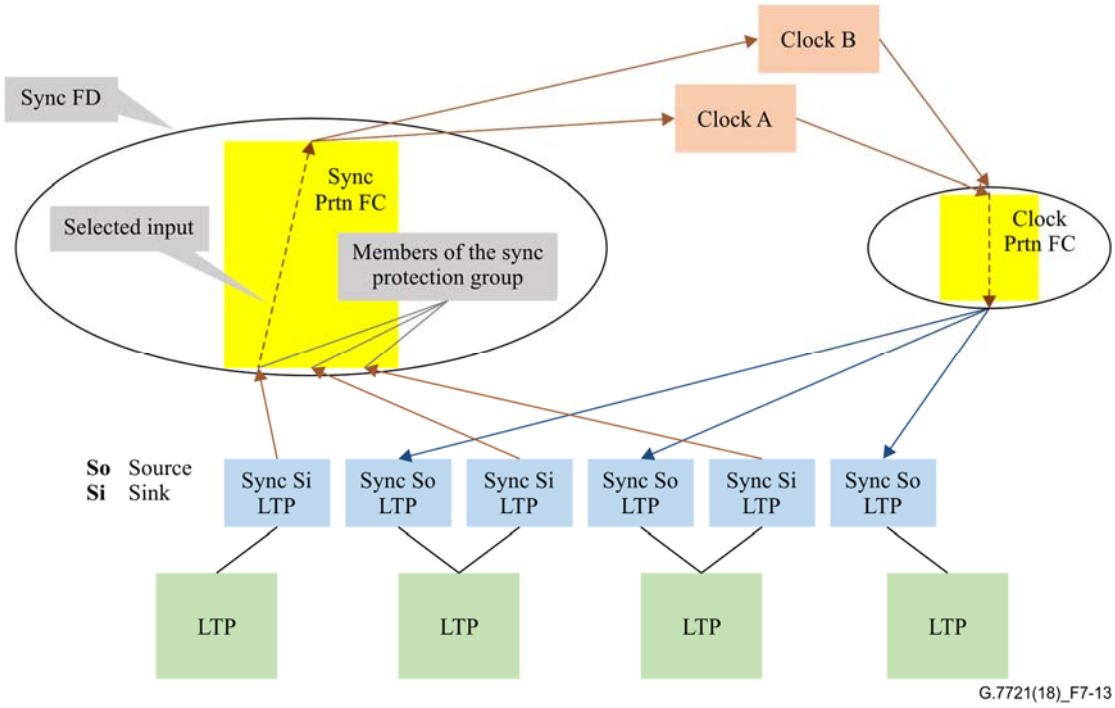


Figure 7-13 – Example of an NE with redundant internal clocks

An example where the sync protection status is reported by the clock is provided below in Figure 7-14.

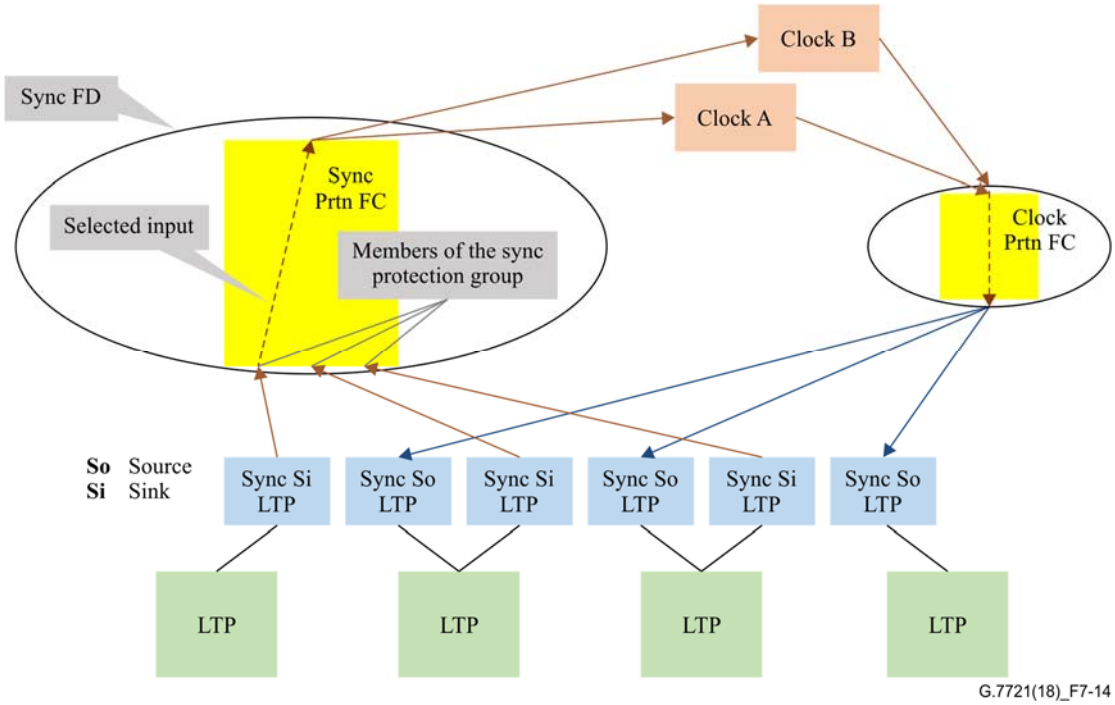


Figure 7-14 – Example of the clock reporting the sync protection status

An example of a station clock that is defined in [ITU-T G.781] is given in Figure 7-15. The station clock can be implemented by configuring the selected sync input directly to the output of the station clock.

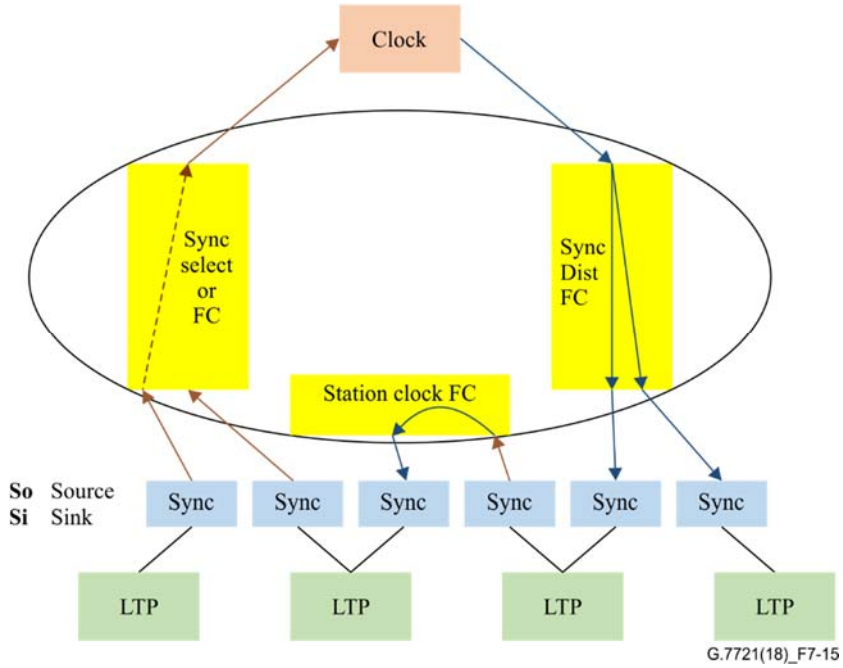


Figure 7-15 – Example of station clock

7.1.4 Synchronization network topology

The information in clauses 6.1 to 6.3 is focussed on the management of a single node. Information on the synchronization network topology is provided below.

Figure 7-16 shows a (simple) example of a synchronization network.

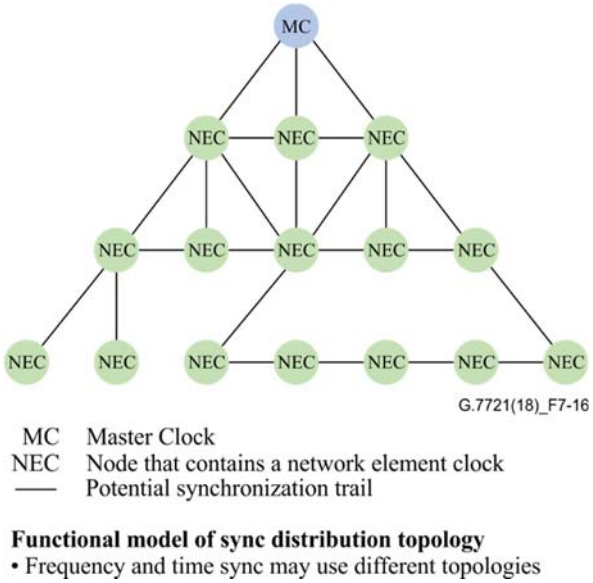


Figure 7-16 – Example synchronization distribution network

From a management perspective, the master clock can be represented by an instance of the clock and the node containing a network equipment clock can be represented by instances of forwarding domains with links to interconnect the nodes. Typically, only a subset of the links in a network are enabled, by management/control actions, to support the transfer timing information. Two types of information may be carried over these links: The timing information (frequency or time stamp) and (optionally) information about the source of the timing information. These links are typically used to carry both timing information and network traffic but some may be dedicated to synchronization. This is illustrated in the Figure 7-17 below.

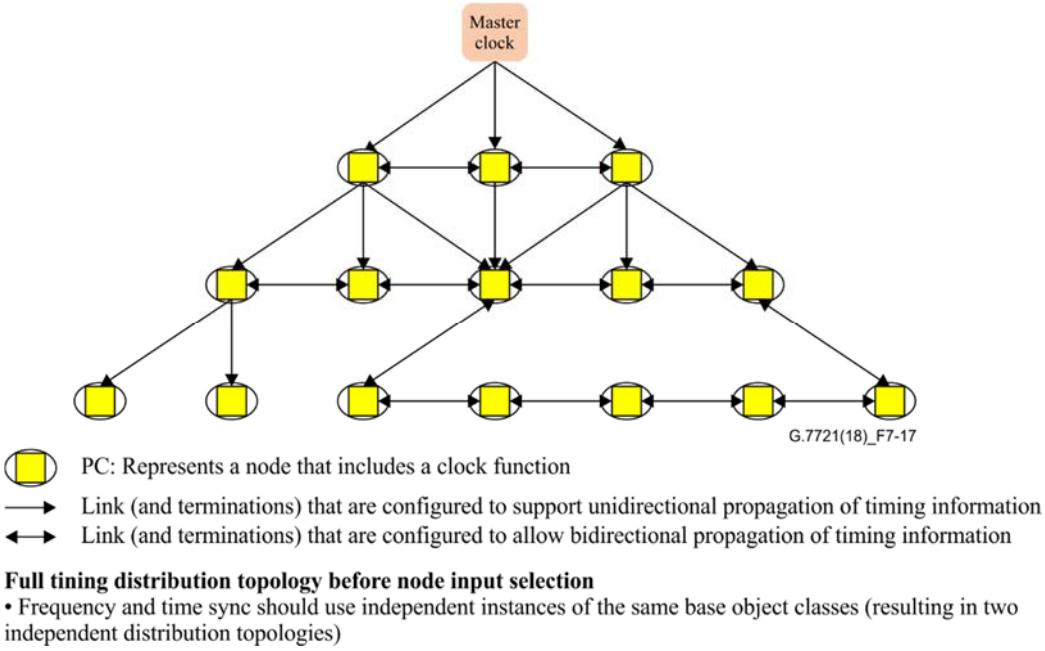


Figure 7-17 – Full timing distribution topology

This view shows all the links that could be used to carry timing information. The configuration of the FCs in the FDs that reduces this topology is shown in Figure 7-18 below.

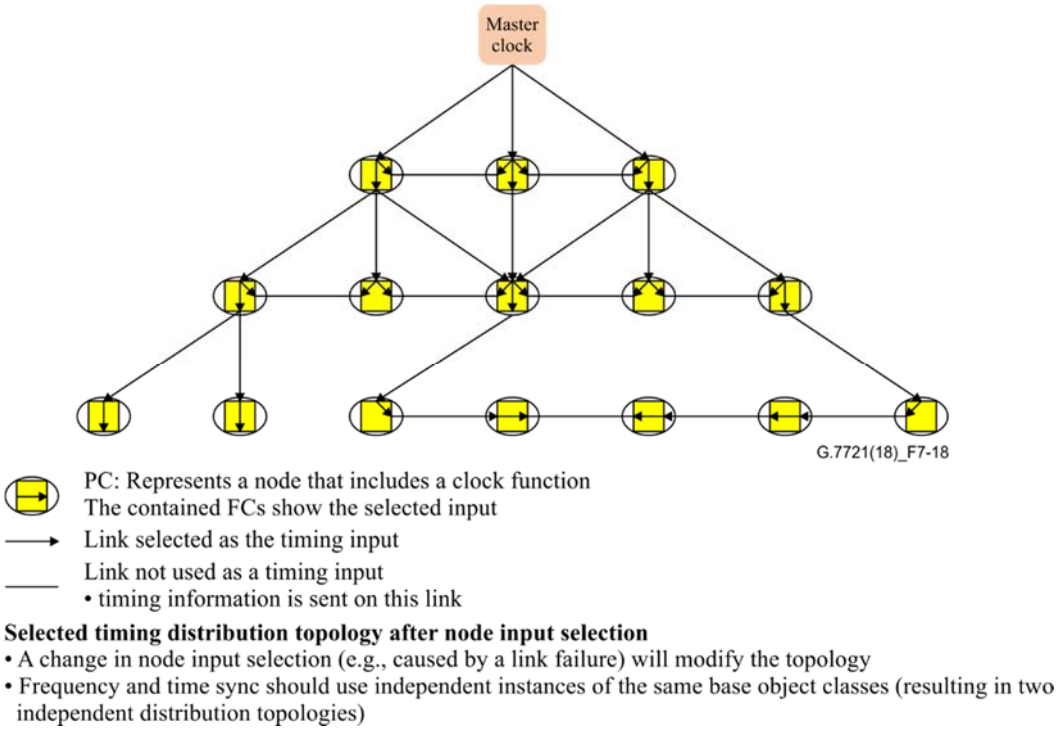


Figure 7-18 – Reduced/selected timing distribution topology

The topology selected topology could be defined manually, or by allowing the nodes to be autonomously configured by a PTP (using BCMA) or sync status messages, or a combination of manual and autonomous configuration. If a degree of autonomous control is permitted, then the selected topology will be updated when a failure occurs. Typically, a network operator would define the set of inputs that are used in the autonomous selection process and the priority assigned to each of these enabled inputs.

To ensure correct operation of the synchronization network the input used by the network element clocks should, when possible, be derived from the master clock. It is essential that, under fault conditions, the formation of timing loops is prevented.

Standard SSM messages only provide clock quality information which is insufficient to guarantee loop-free operation under fault conditions so the links that are enabled to support timing information must be selected to avoid timing loops.

The PTP protocol provides both clock quality information and additional information about the clock source including its identity and domain membership. This allows the BCMA to select the best quality input, from those clocks within the timing domain, and avoid timing loops.

The simple network example shows a single master clock; however, in a typical synchronization network additional (secondary) master clocks are present.

7.1.5 Description of UML model

For better understanding and review of the synchronization UML model, see clause 8. This clause describes a model skeleton and approaches of the UML model.

7.1.5.1 Skeleton of synchronization model

This synchronization model takes the synchronization skeleton of [ITU-T G.7711] as the base. For a specific description of the synchronization skeleton see Annex B.1.3 and Appendix XI of [ITU-T G.7711]. The synchronization skeleton of [ITU-T G.7711] is refactored in the synchronization model of this Recommendation for some specific applications. For the modified synchronization skeleton, see Figure 7-19.

For decoupling from [ITU-T G.7711], the spec model approach of [ITU-T G.7711] is applied. The object classes ConstraintDomain, Clock, LTP and CASC are specified by attribute packages, as described in clauses 7.1.5.2 to 7.1.5.5.

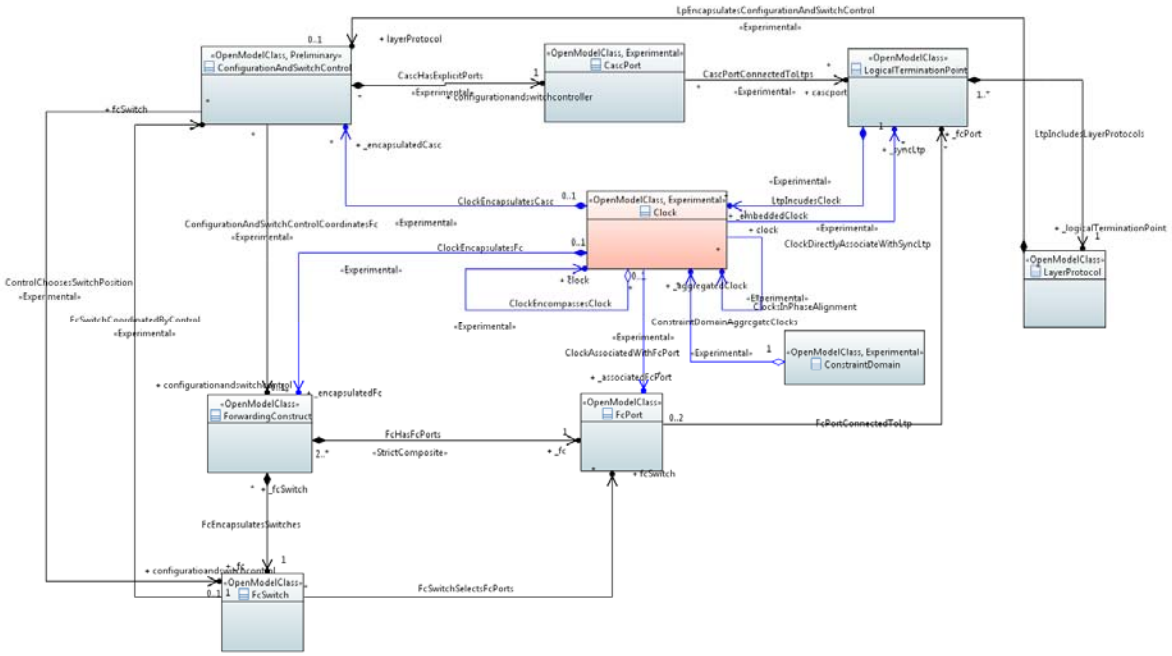


Figure 7-19 – UML model diagram – ClockInContext

7.1.5.2 Specific view of Sync LTP

Figure 7-20 describes the specific structure of Sync LTP. A new object class SyncLpSpec is used to contain the attribute packages defined in clause 7.2.3 and specify the LayerProtocol of LTP in [ITU-T G.7711].

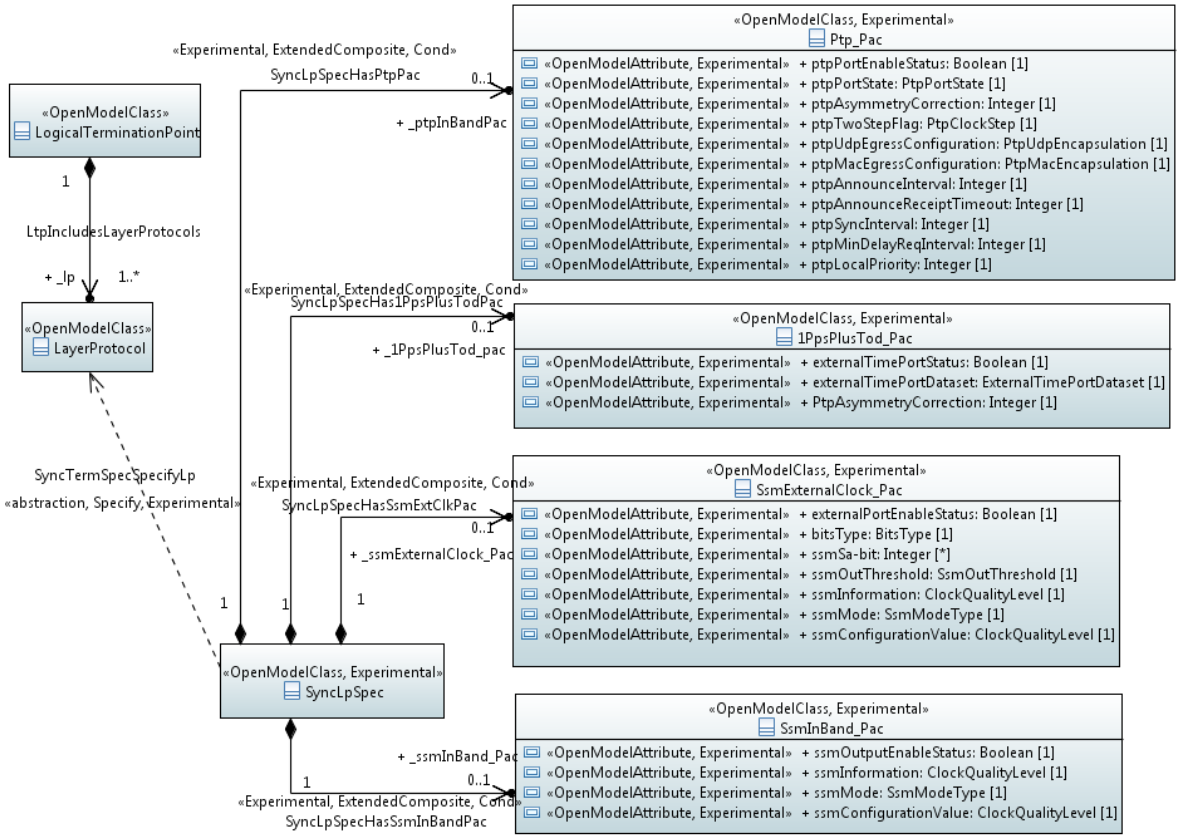


Figure 7-20 – UML model diagram – LtpSpecificView

7.1.5.3 Specific view of ConstraintDomain

As the object class ConstraintDomain can represent the PTP domain and NE, an object class SyncCdSpec that specifies the ConstraintDomain is created to contain two conditional packages the PtpDomainConstraint_Pac and NeSync_Pac. For the specific model view of ConstraintDomain, see Figure 7-21.

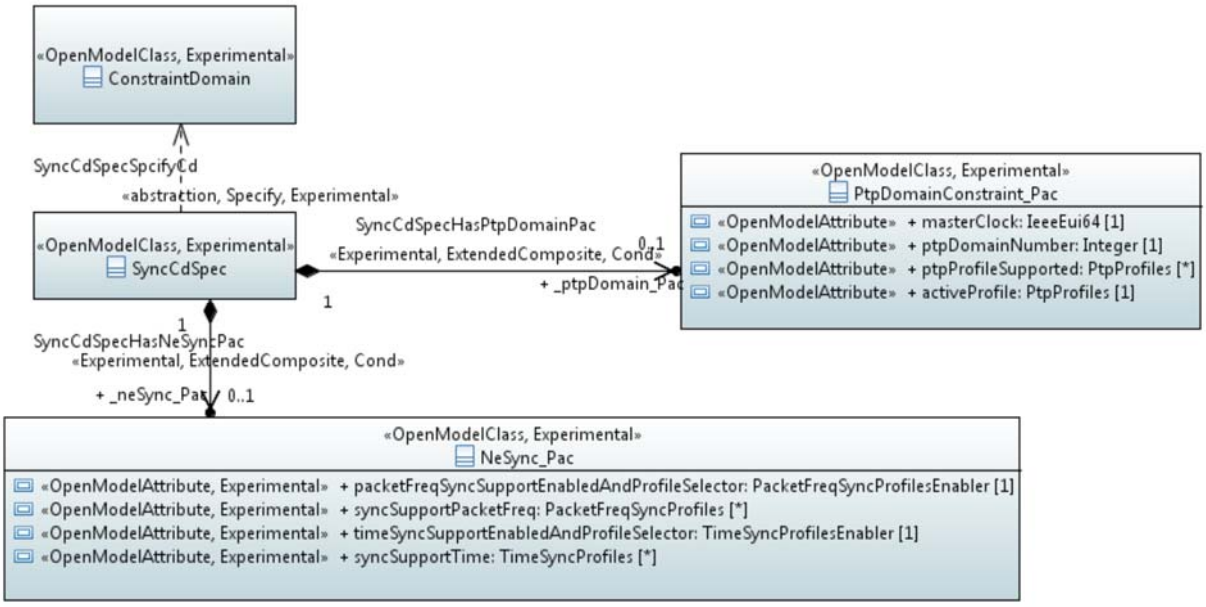


Figure 7-21 – UML model diagram – CdSpecificView

7.1.5.4 Specific view of Clock

Figure 7-22 describes the specific structure of Clock. The Clock object class is specified by ClockSpec which contains two attribute packages defined in clause 7.2.2.

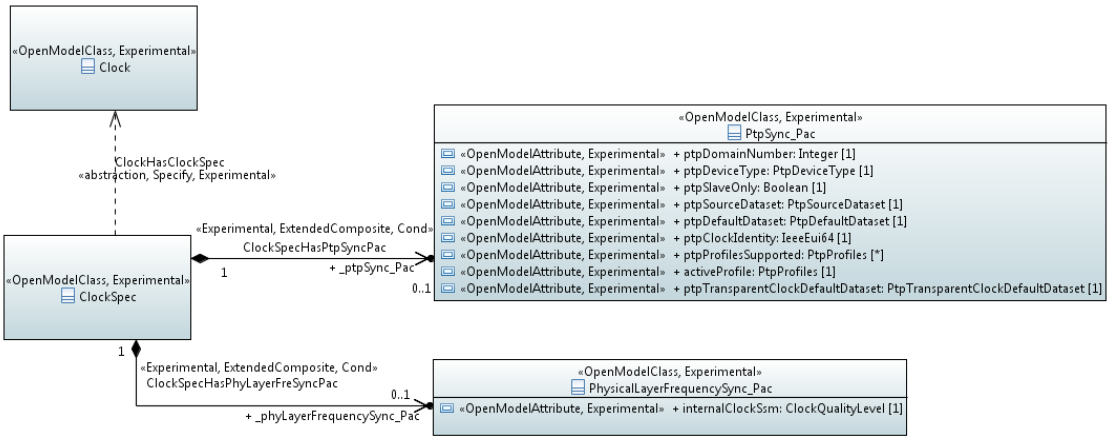


Figure 7-22 – UML model diagram – ClockSpecificView

7.1.5.5 Specific view of CASC

Figure 7-23 describes how the SyncProtectionSpec is contained in the CASC (ConfigurationAndSwitchControl) of [ITU-T G.7711].

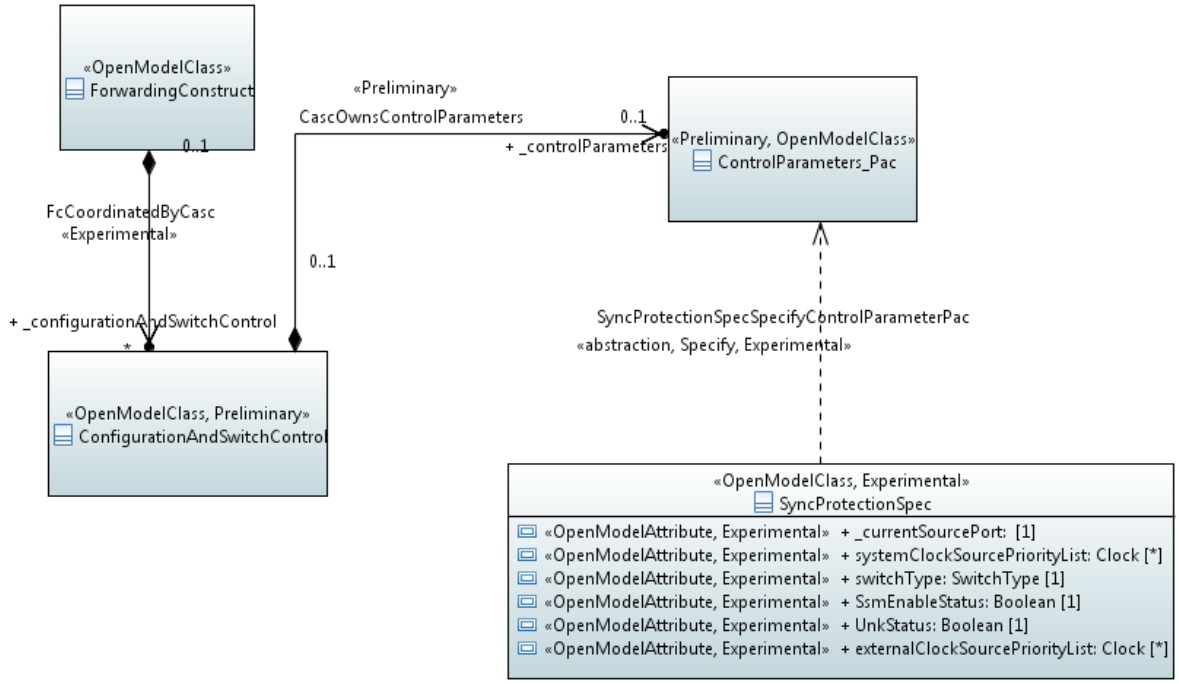


Figure 7-23 – UML model diagram – CascSpecificView

7.2 Synchronization model attributes

7.2.1 Existing NE object

Add NE sync status:

Table 1 – Add NE sync status

Attribute name	Description	Type	Related Recommendations
Sync_Support_Physical_freq	Indicates whether the NE has the capability to support physical layer frequency synchronization.	Boolean – Read only	Physical layer frequency: [ITU-T G.781]
Sync_Support_Packet_freq	Indicates whether the NE has the capability to support packet frequency synchronization and which frequency profile to support.	Enumeration – Read only: G.8265.1 G.8275.2	Packet frequency: [ITU-T G.8265.1] [ITU-T G.8275.2]
Packet Freq Sync support enabled and Profile selector	Allows which packet frequency sync functions to be enabled.	Enumeration – Read/Write: Enable G.8265.1 Enable G.8275.2 Disable	Packet frequency: [ITU-T G.8265.1] [ITU-T G.8275.2]
Sync_Support_time	Indicates whether the NE has the capability to support time synchronization and which time profile to support.	Enumeration – Read only: G.8275.1 G.8275.2	[ITU-T G.8275.1] [ITU-T G.8275.2]
Time Sync support enabled and Profile selector	Allows which time sync profiles to be enabled.	Enumeration – Read/Write: Enable G.8275.1 Enable G.8275.2 Disable	[ITU-T G.8275.1] [ITU-T G.8275.2]

7.2.2 Clock

7.2.2.1 Physical layer frequency sync (SSM) pac

Table 2 describes the physical layer frequency sync (SSM) pac.

Table 2 – Physical layer frequency sync (SSM) pac

Attribute name	Description	Type	Related Recommendations
system clock ID	The ID of the SyncClock_Frequency object.	Object ID – Read only: frequ and PTP could use a common attribute definition	[ITU-T G.8264] (extended SSM)
associated node ID	The SyncClock_Frequency object is associated with the NE of this node ID.	Object ID – Read only: frequ and PTP could use a common attribute definition	

Table 2 – Physical layer frequency sync (SSM) pac

Attribute name	Description	Type	Related Recommendations
run-mode	The run mode of the frequency system clock, such as free run, locked, and hold over.	Enumeration – Read only: free run, locked, hold over. frequ and PTP could use a common attribute definition	[ITU-T G.781]
internal clock SSM	The SSM quality level of internal clock of the NE.	Enumeration – Read only Use the clock quality levels listed in clause 5.4.1 of [ITU-T G.781]. For the corresponding SSM codes and enhanced SSM codes for SyncE refer to Table 11-7 and Table 11-8 of [ITU-T G.8264]. frequ and PTP could use a common attribute definition	[ITU-T G.781] [ITU-T G.8264]

7.2.2.2 PTP sync pac

Table 3 describes the PTP sync pac.

Table 3 – PTP sync pac

Attribute name	Description	Type	Related Recommendations
PTP clock identity	The ID of the SyncClock_Time object.	Object ID with EUI-64 format – Read only: frequ and PTP could use a common attribute definition	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
associated node ID	The SyncClock_Time object is associated with the NE of this node ID.	Object ID – Read only: frequ and PTP could use a common attribute definition	
run-mode	The run mode of the PTP system clock, such as tracing and non-tracing.	Enumeration – Read only: free run, locked, hold over. frequ and PTP could use a common attribute definition	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP domain	The PTP domain number of the NE.	Integer or string – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]

Table 3 – PTP sync pac

Attribute name	Description	Type	Related Recommendations
PTP device-type	Three PTP device types are included: boundary clock (BC), transparent clock (TC), and ordinary clock (OC).	Enumeration – Read only boundary clock (BC), transparent clock (TC), and ordinary clock (OC). frequ and PTP could use a common attribute definition with different enumerations	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP slaveonly	Indicates whether the NE can only be used as PTP slave or not.	Boolean – Read only	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP source dataset	The PTP status dataset of current tracing source.	Ordered list – Read only: grandmasterIdentity – Object ID – Read only, parent ID – Object ID – Read only, priority 1 – Integer – Read only, priority 2 – Integer – Read only, clockClass – Integer – Read only, clockAccuracy – Integer – Read only, offsetScaledLogVariance – Integer – Read only, timesource – Enumeration – Read only, stepsRemoved – Integer – Read only, currentUtcOffset – Integer – Read only, ptpTimescale – Enumeration – Read only, timeTraceable – Boolean – Read only, frequencyTraceable – Boolean – Read only, 1588 protocol version – Integer – Read only, current absolute time – Integer – Read only.	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP default dataset	The PTP status dataset of internal clock of the NE	Ordered list – Read/Write: CLK ID – Object ID – Read/Write, priority 1 – Integer – Read/Write, priority 2 – Integer – Read/Write, clockClass – Integer – Read/Write, accuracy – Integer – Read/Write, offsetScaledLogVariance – Integer – Read/Write, timesource – Integer – Read/Write, stepsRemoved – Integer – Read/Write, 1588 protocol version – Integer – Read/Write, maxStepsRemoved – Integer – Read/Write, (only for [ITU-T G.8275.1]), localPriority – Integer – Read/Write.	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]

Table 3 – PTP sync pac

Attribute name	Description	Type	Related Recommendations
PTP transparent clock default dataset	The PTP status dataset of internal transparent clock of the NE	primaryDomain – PTP domain identity – Read/Write	[ITU-T G.8275.1]

7.2.3 Sync LTP

Note that the model uses the terminationDirection attribute of the LTP to indicate that the Sync LTP is a source or sink LTP, e.g., Sync source LTP with terminationDirection as SOURCE, Sync sink LTP with terminationDirection as SINK.

7.2.3.1 SSM in band pac

All of the attributes that report/manage the SSM quality level can use a common enumeration.

Table 4 describes the SSM in band pac.

Table 4 – SSM in band pac

Attribute name	Description	Type	Related Recommendations
clock port ID	The ID of the SyncLTP_In_Band_Clock object.	Object ID – Read only	
associated port ID	The SyncLTP_In_Band_Clock object is associated with the physical port LTP of this port ID.	Object ID – Read only	
SSM output enable status	Indicates whether to send SSM messages or not.	Boolean – Read/Write	[ITU-T G.781]
SSM information	Current input and output SSM quality levels used by the port. The port should have SSM quality levels for input and output respectively.	Enumeration – Read only: Use the clock quality levels listed in clause 5.4.1 of [ITU-T G.781]. For the corresponding SSM codes and enhanced SSM codes for SyncE refer to Table 11-7 and Table 11-8 of [ITU-T G.8264].	[ITU-T G.781] [ITU-T G.8264]
SSM mode	Indicates whether to use manual or automatic input and output SSM quality levels. SSM mode should be set for input and output respectively.	Enumeration – Read/Write: Manual Automatic	[ITU-T G.781]
SSM configuration value	The input and output SSM quality levels set manually. The SSM quality levels should be manually configurable for input and output respectively.	Enumeration – Read/Write	[ITU-T G.781] [ITU-T G.8264]

7.2.3.2 SSM external clock pac

Table 5 describes the SSM external clock pac.

Table 5 – SSM external clock pac

Attribute name	Description	Type	Related Recommendations
external port ID	The ID of the SyncLTP_External_Clock object.	Object ID – Read only	
external port enable status	Indicates whether to enable this external port or not.	Boolean – Read/Write	
bits-type	The type of this port, such as 2048kb/s or 2048kHz.	Enumeration – Read only	[ITU-T G.781]
SSM sa-bit	Indicates which sa-bit bits are used for carrying input and output SSM quality levels. The port should have sa-bit bits for input and output respectively.	Enumeration – Read/Write	[ITU-T G.781]
SSM out-threshold	The external port stops transmitting when the SSM quality level is lower than the threshold.	Enumeration – Read/Write	[ITU-T G.781]
SSM information	Current input and output SSM quality levels used by the port. The port should have SSM quality levels for input and output respectively.	Enumeration – Read only	[ITU-T G.781] [ITU-T G.8264]
SSM mode	Indicates whether to use manual or automatic input and output SSM quality levels. SSM mode should be set for input and output respectively.	Enumeration – Read/Write: Manual or Automatic	[ITU-T G.781]
SSM configuration value	The input and output SSM quality levels set manually. The SSM quality levels should be manually configurable for input and output respectively.	Enumeration – Read/Write	[ITU-T G.781] [ITU-T G.8264]

7.2.3.3 PTP pac

Table 6 describes the PTP pac.

Table 6 – PTP pac

Attribute name	Description	Type	Related Recommendations
PTP port ID	The ID of the SyncLTP_PTP object.	Object ID – Read only	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
associated port ID	The SyncLTP_PTP object is associated with the physical port LTP of this port ID.	Object ID – Read only	

Table 6 – PTP pac

Attribute name	Description	Type	Related Recommendations
PTP port enable status	Indicates whether to enable this PTP port or not.	Boolean – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP port state	The current PTP state of the PTP port, such as master, slave, passive, initializing, listening, premaster, uncalibrated and faulty.	Enumeration – Read only	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP asymmetry-correction	The asymmetry correction value of this PTP port.	Integer – Read/Write, nanoseconds Same as external time port delay compensation	[ITU-T G.8275.1] [ITU-T G.8275.2]
PTP two step flag	Indicates whether one-step or two-step mechanism is adopted.	Enumeration – Read only	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP udp-egress configuration	The configuration of PTP UDP encapsulation, including destination IP address and IPv4/IPv6 protocol.	Ordered list – Read/Write: destination IP address – String – Read/Write IPv4/IPv6 protocol – Enumeration – Read/Write	[ITU-T G.8275.2] [ITU-T G.8265.1]
PTP mac-egress configuration	The configuration of PTP MAC encapsulation, including destination MAC address and VLAN configuration.	Ordered list – Read/Write: destination MAC address – String – Read only VLAN configuration – String – Read/Write	[ITU-T G.8275.1]
PTP announce-interval	The sending interval of PTP announce message.	Integer: milliseconds – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP announce receipt-timeout	It is used for fault detection of PTP announce messages.	Integer: milliseconds – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP sync-interval	The sending interval of PTP Sync message.	Integer: milliseconds – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP min-delayreq-interval	The sending interval of PTP Delay_req message.	Integer: milliseconds – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]
PTP masterOnly	The per-port attribute masterOnly.	Boolean – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2]
PTP localPriority	The per-port attribute localPriority.	Integer – Read/Write	[ITU-T G.8275.1] [ITU-T G.8275.2] [ITU-T G.8265.1]

7.2.3.4 1PPS + ToD pac

Table 7 describes the 1PPS + ToD pac.

Table 7 – 1PPS + ToD pac

Attribute name	Description	Type	Related Recommendations
external port ID	The ID of the SyncLTP_External_Time object.	Object ID – Read only	
external time port status	Indicates whether this external time port is used as an input or output port.	Boolean – Read only	
external time port dataset	The status dataset of this port	Ordered list – Read/Write: grandmasterIdentity – Object ID – Read/Write priority 1 – Integer – Read/Write priority 2 – Integer – Read/Write clockClass – Integer – Read/Write accuracy – Integer – Read/Write offsetScaledLogVariance – Integer – Read/Write timesource – Integer – Read/Write stepsRemoved – Integer – Read/Write currentUtcOffset – Integer – Read/Write	[ITU-T G.8271]
external time port delay compensation	The delay compensation value of this external port.	Integer – Read/Write: nanoseconds Same as PTP asymmetry-correction	[ITU-T G.8271]

7.2.4 Sync protection FC pac

Table 8 describes the Sync protection FC pac.

Table 8 – Sync protection FC pac

Attribute name	Description	Type
current source port ID	The ID of the clock port traced by the frequency system clock currently.	Object ID – Read only
system clock source priority list	The list is used to select the clock port. It is composed of clock port IDs in the order of priorities.	List of object ID – Read/Write
switch type	Three switch types are included: lockout, manual switch and forced switch.	Enumeration – Read/Write Need more discussion on meaning of lockout/manual/forced
switch mode	Indicates whether to switch to the previously failed synchronization source after its recovery.	Enumeration – Read/Write

Table 8 – Sync protection FC pac

Attribute name	Description	Type
Wtr	Wait to restore time. A previously failed synchronization source is only again considered as available by the selection process if it is fault-free for wtr time.	Integer – Read/Write Unit of minutes: Default value: 15 minutes
SSM enable status	In an automatic reference selection process, if SSM is enabled, the selection of clock source is performed based on SSM and priority; otherwise the selection depends on priority only.	Boolean – Read/Write
UNK status	Indicates whether to take the UNK as one of the SSM quality levels or not. If UNK is enabled, its level lies between PRC and SSU_T; otherwise it is taken as DNU.	Boolean – Read/Write
external clock source priority list	The list is used to select the output clock source for this external clock port. It is composed of IDs of system clock and in-band clock ports in the order of priorities.	Object id – Read only Enumeration – read/write

7.2.5 PTP domain constraint pac

Table 9 describes the PTP domain constraint pac.

Table 9 – PTP domain constraint pac

Attribute name	Description	Type	Related Recommendations
masterClock	The ID of the grandmaster clock in the PTP domain.	Object ID – Read only	[ITU-T G.8275]
ptpDomainNumber	The PTP domain number.	Integer – Read/Write Default: 24	[ITU-T G.8265.1] [ITU-T G.8275.1] [ITU-T G.8275.2]
ptpProfileSupported	The PTP profile the PTP domain supports.	List of PTP profiles – Read/Write: ptpProfile – Enumeration – Read only: G.8265.1 G.8275.1 G.8275.2	[ITU-T G.8265.1] [ITU-T G.8275.1] [ITU-T G.8275.2]
activeProfile	The current active PTP profile in the supported PTP profile list.	Enumeration – Read/Write : G.8265.1 G.8275.1 G.8275.2	[ITU-T G.8265.1] [ITU-T G.8275.1] [ITU-T G.8275.2]

8 UML model file

Information model files with a data dictionary and accompanying profile files are specified using the "Papyrus" modelling tool. These files are provided in the electronic attachment to this Recommendation, which can be downloaded from this repository.

NOTE – The ITU-T G.7721 UML information models and the Open Model Profile are specified using the Papyrus open-source modelling tool. In order to view and further extend or modify the information model, one will need to install the open source Eclipse software and the Papyrus tool, which are available at [b-Eclipse-Papyrus]. The installation guide for Eclipse and Papyrus can be found in [b-IISOMI-515].

The versions of the modelling tool and UML model profiles that are used for this model are listed as follows:

1) OpenModel Profile v0.2.13.
2) OpenInterfaceModel Profile v0.0.8.
3) ProfileLifecycle Profile v0.0.4.
4) Eclipse Oxygen.2 Release (4.7.2).
5) Papyrus version 3.2.0.20171206084.
6) Gendoc 0.6.0.

Appendix I

Multilayer sync LTP example

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

Figure A.2 in [ITU-T G.8275] 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.

This example diagram in [ITU-T G.8275] can be rebuilt in [ITU-T G.7711] model form and the result is shown in Figure I.1.

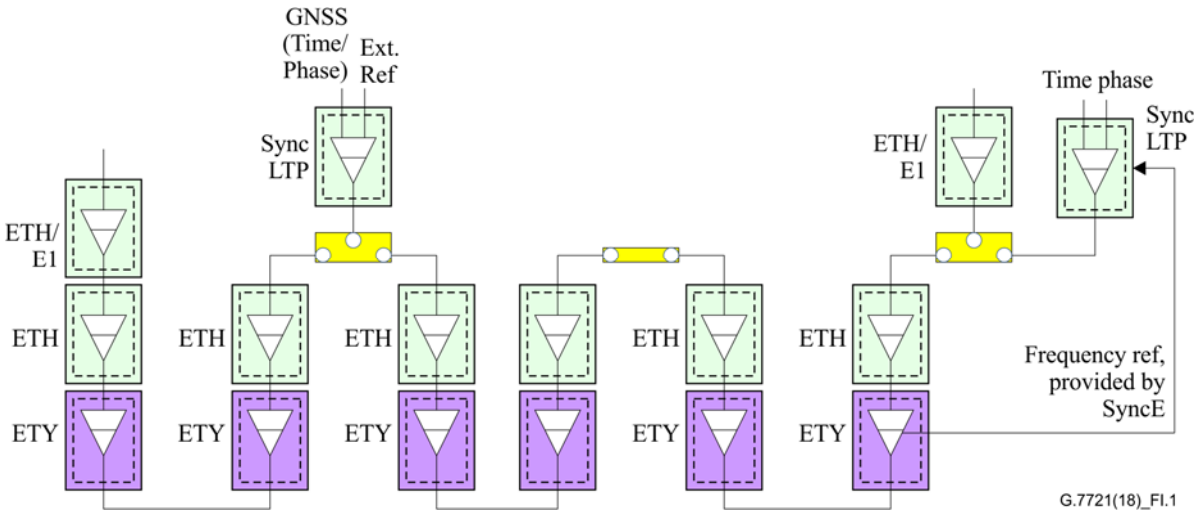


Figure I.1 – Multilayer Sync LTP example diagram

Appendix II

Sync path example

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

Take the topology in Figure 7-17 as an example, the sync paths are shown in Figure II.1 with different colours.

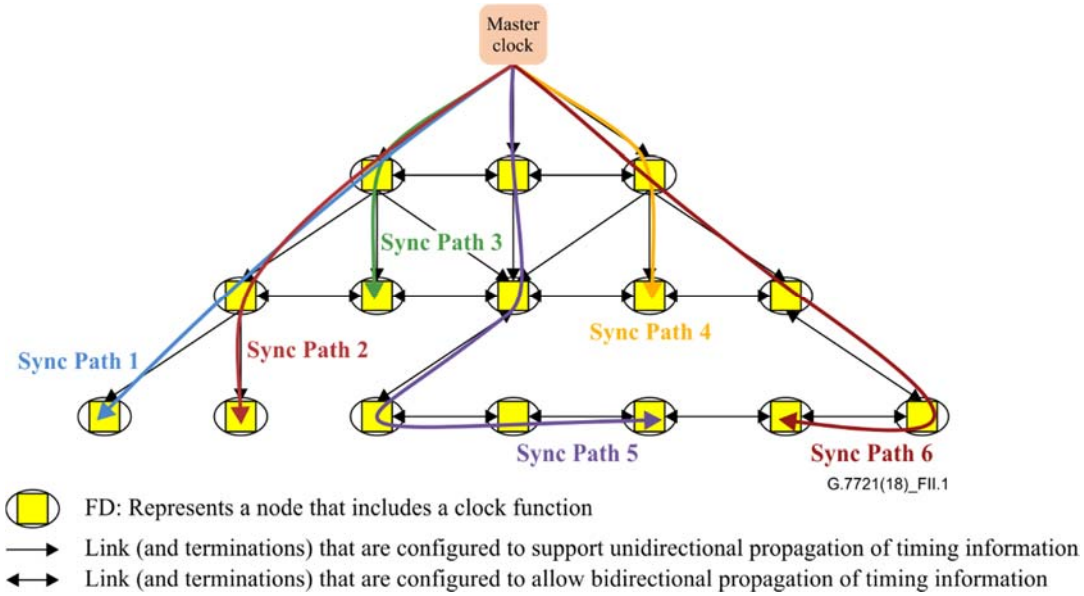


Figure II.1 – Showing sync paths

Note that this approach uses an instance of sync path for each clock on the domain. Note that the figure above does not show the sync path used by the intermediate clocks. As shown above multiple sync paths may transit an intermediate clock, thus each sync path may contain FCs, and clocks that are common to other sync paths. It is not clear if these common elements need to be explicitly shown in the model.

Bibliography

[b-Eclipse-Papyrus] Papyrus Eclipse UML Modelling Tool.
<https://www.eclipse.org/papyrus/>

[b-IISOMI-515] IISOMI-515_Papyrus-Guidelines.docx.
<https://community.opensourcesdn.org/wg/EAGLE/document/171>

[b-ONF TR-512] ONF TR-512 (2015),
<Core Information Model (CoreModel)>

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