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Recommendation

ITU-T G.8264/Y.1364 (2017) Amd. 2 (01/2024)

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SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet protocol aspects – Transport

Distribution of timing information through packet networks

Amendment 2

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Recommendation ITU-T G.8264/Y.1364

Distribution of timing information through packet networks

Amendment 2

Summary

Recommendation ITU-T G.8264/Y.1364 outlines aspects of distribution of timing information through packet networks and initially focuses on Ethernet networks. A number of methods may be used to transfer frequency which may be physical-layer based or protocol-layer based. This Recommendation provides information on architectural aspects of timing flows in Ethernet networks which will form the basis for future work related to time and phase transfer.

This Recommendation specifies the synchronization status message (SSM) protocol and formats for use with synchronous Ethernet. Adherence to the SSM formats specified in this Recommendation is required in order to ensure interoperability between synchronous Ethernet equipment involved in frequency transfer.

Amendment 2 to ITU-T G.8264 (2017) includes the following changes:

- Adds explanation on the use of the terms ETH and ETY in the conventions.
- Corrects references to Tables 11-8 and 11-9 to refer to 11-7 and 11-8, respectively.
- Clarifies wording of the processing of SSM code with enhanced SSM code in clause 11.3.2.1.
- Changes non-inclusive terms.

History *

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Keywords

ESMC, packet timing, physical timing, synchronization, synchronous Ethernet.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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

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Amendment 2

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.8264/Y.1364 (2017) and its Amendment 1.

1 Scope

This Recommendation outlines the requirements on Ethernet networks with respect to frequency transfer. It specifies the synchronization status message (SSM) transport channel namely the Ethernet synchronization messaging channel (ESMC), protocol behaviour and message format.

A number of methods may be used to transfer frequency which may be physical-layer based or protocol-layer based. The method used will be dependent on the actual architecture and what may be supported. This Recommendation focuses on physical layer synchronization. The physical layer that is relevant to this Recommendation is the Ethernet media types defined in [IEEE 802.3]. Other physical layers may also be relevant and may be addressed, along with other packet technologies, in future versions of this Recommendation.

This Recommendation also details the required architecture in formal modelling language. Timing flows are used to describe where and how time and timing will flow through the architecture. Such flows describe what is functionally allowed as an acceptable timing source. Such a source may only be available for use within the equipment or may be available outside as a client service.

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.709] Recommendation ITU-T G.709/Y.1331 (~~2016~~2020), *Interfaces for the optical transport network*.

[ITU-T G.781] Recommendation ITU-T G.781 (~~2017~~2024), *Synchronization layer functions for frequency synchronization based on the physical layer*.

[ITU-T G.803] Recommendation ITU-T G.803 (2000), *Architecture of transport networks based on the synchronous digital hierarchy (SDH)*.

[ITU-T G.805] Recommendation ITU-T G.805 (2000), *Generic functional architecture of transport networks*.

[ITU-T G.809] Recommendation ITU-T G.809 (2003), *Functional architecture of connectionless layer networks*.

[ITU-T G.811] Recommendation ITU-T G.811 (1997), *Timing characteristics of primary reference clocks*.

[ITU-T G.812] Recommendation ITU-T G.812 (2004), *Timing requirements of slave clocks suitable for use as node clocks in synchronization networks*.

[ITU-T G.813] Recommendation ITU-T G.813 (2003), *Timing characteristics of SDH equipment slave clocks (SEC)*.

[ITU-T G.822] Recommendation ITU-T G.822 (1988), *Controlled slip rate objectives on an international digital connection*.

[ITU-T G.823] Recommendation ITU-T G.823 (2000), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy*.

[ITU-T G.824] Recommendation ITU-T G.824 (2000), *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy*.

[ITU-T G.825] Recommendation ITU-T G.825 (2000), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)*.

[ITU-T G.8010] Recommendation ITU-T G.8010/Y.1306 (2004), *Architecture of Ethernet layer networks*.

[ITU-T G.8023] Recommendation ITU-T G.8023 (2018), *Characteristics of equipment functional blocks supporting Ethernet physical layer and Flex Ethernet interfaces.*

[ITU-T G.8261] Recommendation ITU-T G.8261/Y.1361 (~~2013~~2019), *Timing and synchronization aspects in packet networks*.

[ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (~~2015~~2018), *Timing characteristics of ~~a~~ synchronous ~~Ethernet~~ equipment slave clock*.

[IEEE 802] IEEE 802-2014, *IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture*.

[IEEE 802.1AX] IEEE 802.1AX-2014, *IEEE Standard for Local and Metropolitan Area Networks – Link Aggregation*.

[IEEE 802.1Q] IEEE 802.1Q-2022, *IEEE Standard for Local and Metropolitan Area Networks – Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks*.

[IEEE 802.3] IEEE 802.3 (~~2015~~2022), *IEEE Standard for Ethernet*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 network clock [ITU-T G.8261]: The clock generating the network clock signal.

3.1.2 service clock [ITU-T G.8261]: The clock generating the service clock signal.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 Ethernet synchronization message channel: The logical channel carrying the synchronization status message (SSM) code representing the quality level of the synchronous Ethernet equipment clock (EEC), which is bonded to the physical layer. The structure of the channel is provided by an organizational specific slow protocol (OSSP).

3.2.2 non-sync operation mode: A synchronous Ethernet interface configured in non-synchronous mode is an interface that, for the receive side, does not pass the recovered clock to the system clock and is therefore not a candidate reference to the synchronization selection process. It does not process the Ethernet synchronization messaging channel (ESMC) that may be present and therefore cannot extract the quality level (QL) value.

On the transmit side, its output frequency might be synchronized to the synchronous Ethernet equipment clock (EEC), but this remains unknown to the receive interface at the other termination of the link. Indeed, an interface in non-synchronous mode operation does not generate an ESMC and therefore does not transmit a QL.

Such an interface does not participate to the synchronization network and is functionally identical to an asynchronous interface, as defined in [IEEE 802.3].

3.2.3 synchronous operation mode: A synchronous Ethernet interface can be configured in synchronous operation mode.

Its receive side is able to extract the frequency of its input signal and pass it to a system clock (a synchronous Ethernet equipment clock (EEC)) or a better quality clock. It processes the Ethernet synchronization messaging channel (ESMC) and extracts the quality level (QL). This signal can now be used as a candidate frequency reference.

The transmit part of the interface is locked to the output timing of the system clock and generates the ESMC to transport a QL.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAL1	Asynchronous transfer mode Adaptation Layer 1
AI	Adapted Information
ATM	Asynchronous Transfer Mode
BITS	Building Integrated Timing Supply
BS	Base Station
CES	Circuit Emulation Services
CI	Characteristic Information
DNU	Do Not Use
DUS	Do not Use for Synchronization
EEC	synchronous Ethernet Equipment Clock
eEEC	Enhanced Ethernet Equipment Clock
EPL	Ethernet Private Line
ePRC	enhanced Primary Reference Clock
ePRTC	enhanced Primary Reference Time Clock
ESMC	Ethernet Synchronization Messaging Channel
ETH	Ethernet MAC layer network
ETY	Ethernet PHY layer network
EVPL	Ethernet Virtual Private Line
GPS	Global Positioning System

HOP	High Order Path
IWF	Interworking Function
LAG	Link Aggregation
LOP	Low Order Path
LSB	Least Significant Bit
MAC	Media Access Control
MA-M	MAC Address – Medium
MA-S	MAC Address – Small
MPLS	Multiprotocol Label Switching
MTIE	Maximum Time Interval Error
MS	Multiplex Section
NC	Network Controller
NE	Network Element
NTP	Network Time Protocol
OAM	Operation, Administration and Maintenance
OSI	Open Systems Interconnection
OSSP	Organizational Specific Slow Protocol
OTN	Optical Transport Network
OUI	Organizationally Unique Identifier
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PRC	Primary Reference Clock
PRTC	Primary Reference Time Clock
PTP	Precision Time Protocol
QL	Quality Level
QL TLV	Quality Level Type Length Value
RAN	Radio Access Network
RS	Regenerator Section
SASE	Stand Alone Synchronization Equipment
SDH	Synchronous Digital Hierarchy
SETG	Synchronous Equipment Timing Generator
SETS	Synchronous Equipment Timing Source
SRTS	Synchronous Residual Time Stamp
SSM	Synchronization Status Message
SSU	Synchronization Supply Unit
SyncE	Synchronous Ethernet
TDEV	Time Deviation

TDM	Time Division Multiplexing
TLV	Type Length Value
UTC	Coordinated Universal Time
VC	Virtual Container
WAN	Wide Area Network
WDM	Wave Division Multiplexing

5 Conventions

Within this Recommendation, the term "Ethernet" refers to an interface as defined in [IEEE 802.3] and that does not comply with the additional timing requirements of synchronous Ethernet as specified in [ITU-T G.8261], [ITU-T G.8262] and this Recommendation.

This Recommendation defines certain bit sequences that form part of an Ethernet frame. The following conventions are used when specific values are defined.

Binary strings are represented by pairs of hexadecimal characters (octets) each separated by the dash character. This convention is consistent with the representation of hexadecimal strings of data in [IEEE 802.3]. For example, the three-byte ITU-T subtype assigned by the IEEE is represented as 00-19-A7.

In cases where no more than two octets are to be specified, the use of the prefix 0x indicates that the characters are hexadecimal. For example, 0x12 represents the binary bit sequence 00010010.

The term enhanced Ethernet equipment clock (eEEC) refers to a synchronous Ethernet equipment clock (EEC) function as defined in [ITU-T G.8262], but with enhanced performance. The performance of this clock is for further study.

The naming convention for the Ethernet layers ETH and ETY are based on the first version of [ITU-T G.8010]. Some Recommendations [ITU-T G.8023] use the term xTSi[G] in place of ETY. For the purposes of this Recommendation, the terms ETH and ETY are maintained, but may change in a future version of this Recommendation.

6 Packet network architectures

The architectural modelling principles in [ITU-T G.805] and [ITU-T G.809] are well known and have been employed in the development of transport network equipment and networks, and recently in the specification of packet networks. Formal high-level architectural description is necessary to define the underlying details of equipment that are contained in other Recommendations.

[ITU-T G.805] defines properties of architectural components (atomic functions) that allow generic specification of network architectures. These are used, for example, to define trails (i.e., what can be monitored) and sub-network connections (i.e., what can be switched or networked). [ITU-T G.805] was developed to describe traditional (i.e., layer 1) transport networks, and has been recently extended, through [ITU-T G.809], to cover packet networks.

Key points of the architecture include the concept of a layer network, of characteristic information (CI) and of recursion. CI is a signal of a specific format that is transferred over a network connection [ITU-T G.805] or a flow [ITU-T G.809]. A layer network consists of the access points associated with a specific type of CI. Recursion within the layer model allows definitions of underlying layers without restriction. Examples of layer networks below the Ethernet MAC layer (ETH) and Ethernet PHY layer (ETY) could be, for example, that of wave division multiplexing (WDM) or even a duct.

Descriptions have been developed for layer networks related to synchronous digital hierarchy (SDH), asynchronous transfer mode (ATM), Ethernet and multiprotocol label switching (MPLS). It is

important to note that the technologies noted above may contain multiple layers. For example, Ethernet contains the ETY and ETH layers, while SDH contains the regenerator section (RS), multiplex section (MS), high order path (HOP) and low order path (LOP) layers. Due to the recursive nature of the architecture, the same set of interconnection rules apply to any layer network.

For Ethernet, two layer networks are defined: the ETH and ETY. The CI of the ETH layer is the media access control (MAC) frames. The ETY layer is the physical layer that supports the ETH layer (e.g., 10BaseT, 100BaseT). The simplified network model for Ethernet is shown in Figure 4 of [ITU-T G.8010].

6.1 Network layers and synchronization

The layer networks that define a network technology carry information across a network. Carrying this information may result in the information passing over multiple network layers. Crossing a layer is done via an adaptation function from an upper client layer to a lower server layer. The data of the upper client layer, the CI, is adapted by the adaptation function to be the adapted information (AI) and is carried over the server layer. For certain technologies, notably time division multiplexing (TDM) and WDM, timing information is part of the CI that is carried across the network. For example, plesiochronous digital hierarchy (PDH) timing must be carried across the network. SDH adapts the timing information and carries the adapted payload with timing (in the form of stuff control bits) to allow both timing and data to exit the network.

For packet networks, not all layers will include timing information as part of the CI. Timing information is only present at the physical layer. For example, timing information is part of the synchronous ETY layer. Timing information is not part of the CI of the packet layers; therefore, timing is not carried inherently by the packet network. This has implications for certain timing-related services, such as circuit emulation, where client timing needs to be carried across a network. In these cases, for example circuit emulation, alternative methods for carrying timing information are required. The interworking functions (IWFs) described in [ITU-T G.8261] are examples of alternative methods.

6.2 Layer network performance impacts on synchronization

A layer network adapts CI from one layer to become AI of a lower layer (due to the recursive properties of layer networks, this AI is now part of the CI of the lower layer). From the perspective of timing, the adaptation process is not noise free. For example, adapting a PDH client into an SDH virtual container (VC) causes jitter due to the stuff bit mechanism (the control bits are AI), adapting the MS adds jitter and wander due to pointers. For packet networks, the switching function relies on buffering packets, resulting in packet delay variation. For time-sensitive applications, packet delay variation needs to be considered.

7 Timing flows

Timing flows represent timing information that may be carried across a layer network. This timing information may be required to support the needs of a service or those of the network, or be part of the CI of that service. For example, a TDM service must have a clock associated with it and is thus part of the CI that defines the service (e.g., E1 service which meets [ITU-T G.823]).

In existing synchronization networks, the timing information that is carried across the network is often referred to as a timing trail (see [ITU-T G.781]). This follows from the definition of "trail" in [ITU-T G.805]. In the case of packet networks, the concept of a "trail" was extended and called a "flow", first in [ITU-T G.809], to describe the possibly non-continuous nature of traffic and the case where multiple packet streams are carried over a single lower layer network connection. The concept of a timing flow can be considered synonymous with that of a timing trail; however, the use of a timing flow will enable timing to cover both the packet and TDM environments.

For the purposes of physical layer frequency transfer, a timing flow is equivalent to a timing trail.

A layer network may carry multiple timing flows. For example, the SDH network may contain a number of PDH signals mapped into a single synchronous transport module level-N (STM-N) signal. At the PDH layer, each PDH signal has a timing flow associated with it. For a specific service, however, only one timing flow is generally associated with a service. In the case of packet networks, the packet layer may not contain any timing flows (e.g., timing that is part of the CI and thus needs to be carried end-to-end), but the physical layer will always contain a timing flow.

When a service of the network is defined to contain timing as part of its CI, a timing flow through the network must exist (for example, an E1 through SDH provides the timing flow across the SDH/WDM network) and appropriate mechanisms must exist if multiple layer networks are to be traversed (e.g., stuff bits representing the frequency offset are carried across the network).

For the purposes of network synchronization, three categories of timing flow are considered: physical, service and message.

Physical timing flows represent the timing flow associated with the lowest layer network that can be used for synchronization (e.g., synchronous Ethernet, SDH). The physical flows are represented by the bit transitions in a digital network.

Service timing flows represent the timing that is associated with a specific timing-sensitive service (e.g., PDH service timing). Timing flows for these services may be carried over one or more server networks. The functions defined for a layer network specify how the client signals are adapted and carried over a server network. In general, when a client signal has timing information required by the service (e.g., an E1 service), the lower layers are specified to carry this information in some fashion (e.g., the E1 carried over SDH has its timing information encoded in the stuff bytes of the VC12).

In cases where the server layer network does not carry timing intrinsically, specific mechanisms need to be defined to allow client timing to be carried within the server layer network. Doing so allows the timing information of the client to traverse the network. An example of this is TDM circuit emulation over a packet network. A packet network cannot inherently transfer the frequency information of its client, so the timing associated with the PDH client must be contained within the payload of the packet network itself. The carriage of a TDM service over a packet network is often called a *layer violation* since the lower layers cannot encapsulate all of the CI associated with a client network.

A service timing flow may not be associated with an end-user service, but would be associated with the network only. For example, timing distribution over SDH lines is not associated with any end-user service.

Message timing flows represent the third type of flow. These pertain to messages, carried over a layer network, that contain some timing-related information that will be used by an upper layer (e.g., higher than the current layer network) to derive network or service timing. Examples of message flows are network time protocol (NTP) and precision time protocol (PTP).

Message timing flows may be restricted to timing between adaptation points of a network layer only (e.g., in the case of circuit emulation) or may be carried across a layer network. In the case of carriage across a layer network, message flows are typically protocols that operate at layer 2 or layer 3.

Examples of timing flows are shown in Appendix I.

The details of combining time and frequency are for further study.

8 Functional blocks

The network architectures developed by ITU-T are defined in terms of functional models. These models define a set of building blocks that represent specific functions that are used within a network. Functional blocks form the basis for the development of equipment and management Recommendations.

However, the functional architectures have been specified to define the network in terms of the end-to-end transport of user information (e.g., data). In transport networks for which functional models have been defined (e.g., SDH, optical transport network (OTN), PDH), frequency synchronization does not need to be explicitly identified, as the timing is always present with the bearer channel. This clause presents synchronization-specific blocks for use.

Functional blocks that are defined for synchronization may be embedded into network equipment (e.g., [ITU-T G.8262] clocks), or into other equipment such as standalone synchronization equipment (SASE) or a synchronization supply unit (SSU). Functional blocks that are defined for synchronization-related functions include: clock functions, time distribution functions, clock selection functions and IWFs necessary to implement circuit emulation. These are shown in Figure 8-1.

Traditionally, synchronization defined clocks in terms of frequency. The current functional blocks representing clock functions in [ITU-T G.781] only provide frequency. Internal clocks within a network element (NE) may provide a frame start indication; however, this is internal to the NE and not generated by the clock function.

Time distribution is a function that is required within the network, for example, to support time setting for alarm correlation. In order to distinguish time distribution from frequency distribution, two symbols are provided. A special functional block combining both time and frequency is provided in Figure 8-2. Details are for further study.

As noted above, traditional synchronization is based on distributing a frequency. This frequency is usually bound to the underlying bearer channel. In this case, the timing source origination and termination are contained within the appropriate functional models. No explicit depiction is needed. However, in the case of a packet stream representing a timing flow, specific timing origination and termination descriptors have been used. These are illustrated in Figure 8-3. Usage is for further study.

Additional functional blocks may be defined, but are for further study. Examples of how these blocks may be used for circuit emulation services (CES) are provided in Appendix II.

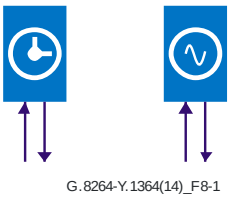

Figure 8-1 – Time and oscillator (frequency) functions

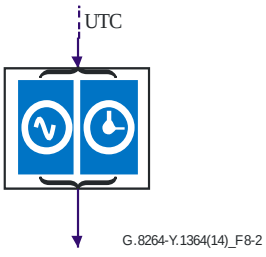

Figure 8-2 – Combined clock (time and frequency)

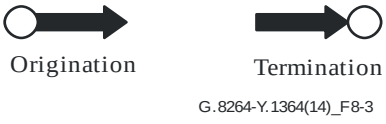

Figure 8-3 – Timing flow origination and termination

9 Next generation timing architectures

9.1 Current synchronization based on SDH

Network synchronization has traditionally been associated with the distribution of a precise frequency throughout a network. This has been accommodated by the use of a combination of network and equipment clocks and, possibly, some form of inter-office timing transfer mechanism. Clocks within the network have been categorized based on performance, and a synchronization scheme where synchronization is distributed from a primary reference clock to clocks of lower quality~~master/slave synchronization scheme~~ is employed. In some cases, the use of satellite for the distribution of frequency is used (e.g., global positioning system (GPS)). The clocks in the current network are defined in [ITU-T G.811], [ITU-T G.812] and [ITU-T G.813]. General network architecture is described in [ITU-T G.803].

Inter-office timing distribution has evolved to include SDH as a key component in network synchronization distribution. As a result, the overall network synchronization architecture is described in [ITU-T G.803]. Functions specific to synchronization are also defined in [ITU-T G.781].

9.2 Synchronization performance

The performance of clocks within synchronization networks are based on the need to maintain acceptable slip performance based on the requirements in [ITU-T G.822]. Jitter and wander will accumulate in a network, and are controlled through correct network and equipment design. As a result of standardization, synchronization performance is controlled within the network so that specific interface requirements are met throughout the network. These limits are defined in [ITU-T G.823] and [ITU-T G.824] for PDH networks and in [ITU-T G.825] for SDH networks. Interface limits for CES are defined in [ITU-T G.8261].

9.3 Network evolution

The transport network is required to meet the jitter and wander requirements of the services that may be carried over the network. The current synchronization network has evolved to meet the slip objectives necessary to ensure adequate performance of voice, which was largely carried over DS-1 and E1 circuits.

However, traffic on the current network is no longer dominated by voice, but by packet data. Due to the nature of packet transport, the strict synchronization requirements of the voice network are not needed for pure packet services, as these services may be subject to significant buffering (e.g., e-mail). However, as the packet network technology begins to replace TDM (e.g., SDH) technology as the primary service interface technology, the need to maintain a synchronization network will remain in order to enable the support of certain services (e.g., circuit emulation) or to support specific infrastructure requirements (e.g., wireless).

9.4 Next generation synchronization networks

Networks are evolving from those providing connectivity for circuit switched services to those providing connectionless service capability (e.g., Internet). In terms of network synchronization, the synchronization network can be considered to be a form of a circuit switched network, in that the objective of synchronization distribution is to distribute the timing signal across a deterministic path in the network. These paths may be disjoint from any specific service path (e.g., clock signals do not terminate at the same points in the network where the service terminates) and have to be managed accordingly (separate from traffic, as possibly an overlay network).

9.4.1 Synchronous Ethernet

It is expected that synchronization networks will evolve, as packet network technology replaces TDM network technology. ITU-T has specified synchronous Ethernet that allows the distribution of

frequency to be provided over Ethernet physical links. This concept is described in [ITU-T G.8261], and allows support for timing distribution in a manner consistent with SDH frequency-based timing distribution. Network equipment clocks used for synchronous Ethernet are defined in [ITU-T G.8262] and have been specified to be compatible with the synchronization distribution capabilities of existing SDH-based networks. As a result, network engineering remains consistent with existing practices.

9.4.2 Packet timing mechanisms

Time distribution relates to the transfer of time rather than frequency. Frequency is a relative measure but is generally assumed to be measured relative to a frequency standard. Time differs from frequency in that it represents an absolute, monotonically increasing value that can be generally traced to the rotation of the earth (e.g., year, day, hour, minute, second).

Mechanisms to distribution time are significantly different than those used to distribute frequency. As a label, time is carried as a machine-readable string. Protocols exist that operate at specific layers that carry time distribution protocols (e.g., [b-IETF RFC 1305], [b-IETF RFC 3550] and [b-IEEE 1588]). Different protocols may have different levels of resolution of time.

Timestamps may be used in some network applications to support generation of frequency. The notion of time carried by these timestamps compared with the time generated by the local oscillator can be used to recover a frequency reference for the local oscillator.

Differential methods can also be used to recover timing from packets. In this case, the timestamp needs only to be a relative and can be used as an estimate of phase. Since phase and frequency are related, it is possible to use this relative information to recreate a frequency reference. This is known as differential timing (see also [ITU-T G.8261]). As an example, synchronous residual time stamp (SRTS) is a well-known method standardized for use in ATM asynchronous transfer mode adaptation layer 1 (AAL1) that allows relative phase to be signalled as a timestamp, to be sent across a packet network to be used to recreate the frequency of a PDH signal.

10 Frequency transfer using synchronous Ethernet

10.1 Synchronous Ethernet: General

Synchronous Ethernet is defined by ITU as a means of using Ethernet to transfer timing (frequency) via the ETY layer. This is a general case of layer 1 timing and was introduced in [ITU-T G.8261].

Clocks for use in synchronous Ethernet have been defined in [ITU-T G.8262] and are compatible with the clocks used in the existing synchronization network. As a result, network synchronization design remains consistent with existing network synchronization practice. Jitter and wander remain compatible with existing Recommendations (see [ITU-T G.8262]).

The [IEEE 802.3] standards require that the line rate of Ethernet operate within a specific rate (±100 ppm) relative to an absolute reference. Synchronous Ethernet simply states that this rate traceable to an external reference. Because of this, synchronous Ethernet does not impose any restrictions on existing Ethernet devices that do not require synchronous capabilities. However, in cases where frequency recovery using synchronous Ethernet is required, a synchronization status message (SSM) is required.

Synchronous Ethernet ports nominally operate within a frequency tolerance range of ±4.6 ppm. However, in order to operate with non-synchronous interfaces, synchronous Ethernet receivers must also operate at ±100 ppm in order to maintain data continuity.

NOTE – There may be sync Ethernet interfaces with reduced functionality in the sense that they might provide sync Ethernet functionality in a single direction only (transmit or receive). Details are for further study.

SSMs for Ethernet are described in this Recommendation. SSM is intended to be used with the synchronization selection algorithms based on [ITU-T G.781]. However, the full functionality of

SSMs may not be required at all nodes in a network. The ability to receive SSMs is dependent on the application for interfaces that intend to utilize the physical Ethernet layer to extract a network clock. However, the ability to generate SSMs is only required in cases where the NE participates in distribution of network timing. This may have implications for certain implementations that may exist at the edge of a network, where the NE terminates synchronization.

In some application cases, mainly in the access network, it might be possible to recover timing from an Ethernet signal that does not carry an Ethernet synchronization messaging channel (ESMC) channel, and to generate a synchronous Ethernet signal without an ESMC channel. Such usage is under the responsibility of the operator and is for further study.

10.2 Operation modes

Ethernet equipment that are not synchronous-Ethernet capable work in an asynchronous mode, where each input interface gets its timing from its input signal, which is within a frequency range of ±100 ppm (±20 ppm for 10G wide area network (WAN) as per clause 57.6.2 of [IEEE 802.3]) and where each of its output interfaces might have a free-running oscillator generating a timing within a frequency rate of ±100 ppm (±20 ppm for 10G WAN).

Synchronous Ethernet equipment are equipped with a system clock (e.g., a synchronous Ethernet equipment clock). Synchronous Ethernet interfaces are able to extract the received clock and pass it to a system clock.

This equipment clock may work in one of two modes: QL-enabled mode or QL-disabled mode, as specified in [ITU-T G.781]. Each interface of a synchronous Ethernet equipment may be configured to work in either non-synchronous or synchronous operation mode.

Non-synchronous operation mode:

A synchronous Ethernet interface configured in non-synchronous mode is an interface that, for the receive side, does not pass the recovered clock to the system clock and is therefore not a candidate reference to the synchronization selection process. It does not process the ESMC that may be present and therefore cannot extract the QL value.

On the transmit side, its output frequency might be synchronized to the EEC, but this remains unknown to the receive interface at the other termination of the link. Indeed, an interface in non-synchronous mode operation does not generate an ESMC and therefore does not transmit a QL.

Such an interface does not participate to the synchronization network and is functionally identical to an asynchronous interface as defined in [IEEE 802.3].

Synchronous operation mode:

A synchronous Ethernet interface can be configured in synchronous operation mode.

Its receive side is able to extract the frequency of its input signal and pass it to a system clock (an EEC or better quality clock). It processes the ESMC and extracts the QL. This signal can now be used as a candidate frequency reference.

The transmit part of the interface is locked to the output timing of the system clock and generates the ESMC to transport a QL.

In the particular case of Ethernet interfaces for 1G copper as specified in [IEEE 802.3], these interfaces perform link auto-negotiation to determine the ~~master and slave~~ clock~~s~~ reference for the link. In the case where these interfaces are used for synchronous Ethernet, the resulting timing path must be considered if frequency distribution based on synchronous Ethernet is used. The clock ~~master~~ reference must be consistent with the network's synchronization plan.

It is an operator's choice to utilize a synchronous Ethernet interface as a candidate synchronization interface in the absence of ESMC and QL values. Such usage is under the responsibility of the operator and is for further study.

11 SSM for synchronous Ethernet

11.1 Packet-level SSM

For existing SDH-based SSM, the SSM message is carried in fixed locations within the SDH frame. In the case of Ethernet, there is no equivalent of a fixed frame. Overhead for various functions, e.g., pause, operation, administration and maintenance (OAM), is carried via protocols running over the PHY layer. As such, SSM must be carried over a protocol.

Logically, the SDH SSM overhead can be viewed as a dedicated unidirectional communication channel between entities that process SSM messages. Figure 11-1 shows a simplified example of two NEs connected to one another. Each is also connected to an SSU. Selectors are provided within each NE to provide the source selection for the system clock. Selectors are under the control of a block called "sync control". This block is also responsible for controlling timing protection. Not shown in the figure is an interface to the management system.

The sync block may be implemented as software running on a NE and may take as input the quality level (QL) SSM on the various inputs (e.g., the external inputs or the line inputs). The sync control block may also be responsible for generating an SSM on the appropriate outputs to indicate certain conditions (for example, insertion of do not use (DNU) on some ports – see [ITU-T G.781]).

The SSM represents an indication of the QL of the transmitting clock, and hence represents a unidirectional channel between the sync control block in the transmit NE and that of the receive NE.

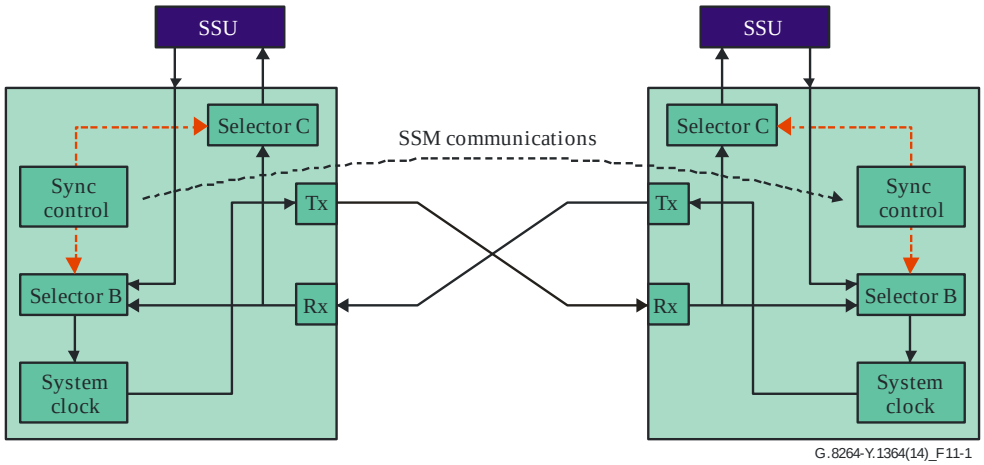

Figure 11-1 – Simplified SSM channel

Figure 11-1 makes no reference to the specific type of channel that is used. In the case of SDH, dedicated overhead is present in the transport overhead. In the case of Ethernet, this does not exist, but a mechanism is required in order to provide this communication ability.

For the case of synchronous Ethernet SSM, the message channel is based on [IEEE 802.3] Link OAM and uses an IEEE organizational specific slow protocol (OSSP) to convey the QL of the respective Ethernet physical signal.

11.1.1 ESMC operation with link aggregation

[IEEE 802.3] defines multiple slow protocols and allows different slow protocols to be used within a single system over a single link segment. With respect to the ESMC, implementations must respect

that the QL applies to the physical layer clock and process the ESMC appropriately. For example, link aggregation (LAG) [IEEE 802.1AX] is another function that utilizes slow protocols and provides a mechanism for carrying MAC frames over a group of links. As noted in [IEEE 802.3] clause 57.2.2, LAG operates above OAM and hence above the ESMC. Since the ESMC is modelled on Link OAM, processing of ESMC messages is therefore required on each synchronous Ethernet enabled link in the LAG group.

It is also important to note that the use of parallel links, such as the case with LAG, needs to be carefully considered due to the potential for creation of timing loops (see clauses 5.13.2 and 5.13.3.1 of [ITU-T G.781]. As noted in clause 5.13.2 of [ITU-T G.781], the concept of a "bundle" is introduced in cases where multiple timing links share the same synchronization source (i.e., the same EEC in the case of synchronous Ethernet). In this situation, which also applies to LAG, when a network element selects one port of a bundle as its synchronization input, it has to return DNU/DUS (do not use/do not use for synchronization) on all timing capable ports of the bundle. It is left to the operators either to configure several synchronous Ethernet enabled ports or only one synchronous Ethernet enabled port of the LAG.

11.2 Sync selection based on SSM

SSM messages represent the QL of the system clocks located in the various NEs. QL refers to the holdover performance of a clock. The two clocks defined for synchronous Ethernet equipment in [ITU-T G.8262] have different characteristics, and slightly different holdover performances.

NOTE – For the purposes of SSM selection, the [ITU-T G.8262] EEC option 1 clock is treated as a [ITU-T G.813] option 1, while the EEC option 2 is treated as an [ITU-T G.812] type IV clock (i.e., QL-SEC and QL-ST3, respectively). The SSM messages are provided in Table 11-1. An extended quality level type length value (QL TLV) is also defined to support clocks with enhanced performance. (These additional clocks and their QL levels are included in Table 11-6.)

Table 11-1 – SSM messages for synchronous Ethernet

Clock	Quality level	SSM code
EEC1	QL-EEC1	0xB
EEC2	QL-EEC2	0xA

Synchronization selection is detailed in Annex A.

11.3 SSM for synchronous Ethernet: Format and protocol

As noted above, clock QL indication is carried via a protocol running over the synchronous Ethernet link. SSMs for Ethernet implement the SSM channel using an [IEEE 802.3] OSSP. Network level SSM is defined in [ITU-T G.781]. Message processing times contained within [ITU-T G.781] are based on network reconfiguration objectives, which are defined based on the performance characteristics of the system clocks (SEC for the case of SDH, EEC for the case of synchronous Ethernet). In order to meet the performance requirements for reference switching in [ITU-T G.781], two types of protocol message types are defined. In general terms, a background or "heart-beat" message is used to provide a continuous indication of the clock QL. A message period of one second meets the message rate requirements of [IEEE 802.3] slow protocols. To minimize the effects of wander that may occur during holdover, an event type message with a new SSM code is generated immediately, subject to the clock processing requirements in [ITU-T G.781]. To protect against possible failure, the lack of messages is considered to be a failure condition. The protocol behaviour is such that the quality level is considered QL-FAILED if no SSM messages are received after a five second period. Details are contained within the following clauses.

11.3.1 ESMC format

The Ethernet SSM is an ITU-T defined Ethernet slow protocol. The IEEE has provided ITU-T with an organizationally unique identifier (OUI) and a slow protocol subtype. These are used to distinguish the Ethernet SSM protocol data unit (PDU). The values assigned by the IEEE are indicated in Table 11-2.

Table 11-2 – IEEE assigned OUI and slow protocol subtype

Organizationally specific identifier	00-19-A7
Slow protocol subtype	0x0A

The quality level is carried in a type length value (TLV) field, which is contained within the ESMC PDU. Two types of ESMC PDU frames are defined and are distinguished by the event flag. These are the ESMC information PDU and the ESMC event PDU.

An NE must discard and not forward upon reception any TLV within the ESMC PDU that it does not recognize.

11.3.1.1 ESMC PDU format

The ESMC PDU format is shown in Table 11-3. The quality level type length value (QL TLV) is shown in Table 11-4.

Table 11-3 indicates the bit and byte locations for the PDU format. The order of transmission is as follows: Octet number 1 in the table is transmitted first. For each octet, the first bit transmitted is the least significant bit (LSB).

The use of an IEEE 802.1Q virtual local area network (VLAN) tag in frames carrying ESMC messages is not allowed. In the case of a clock receiving an ESMC message within a frame containing an IEEE 802.1Q VLAN tag, the clock need not process that ESMC message.

Table 11-3 – ESMC PDU format

Octet number	Size/bits	Field
1-6	6 octets	Destination address = 01-80-C2-00-00-02 (hex)
7-12	6 octets	Source address
13-14	2 octets	Slow protocol Ethertype = 88-09 (hex)
15	1 octet	Slow protocol subtype = 0A (hex)
16-18	3 octets	ITU-OUI = 00-19-A7 (hex)
19-20	2 octets	ITU subtype
21	bits 7:4 (Note 1)	Version
	bit 3	Event flag
	bits 2:0 (Note 2)	Reserved
22-24	3 octets	Reserved
25-1532	36-1490 octets	Data and padding (See point j)
Last 4	4 octets	Frame check sequence (FCS)
NOTE 1 – Bit 7 is the most significant bit of octet 21. Bit 7 to bit 4 (bits 7:4) represent the four-bit version number for the ESMC. NOTE 2 – The three LSBs (bits 2:0) are reserved.		

ESMC PDUs have the following fields in the order specified above:

a) Destination address (DA): This is the IEEE-defined slow protocol multicast address. The format is defined in Annex 57B of [IEEE 802.3].

b) Source address (SA): The source address is the MAC address associated with the port through which the ESMC PDU is transmitted.

c) Slow protocol Ethertype: ESMC PDUs must be type encoded and carry the slow protocol type field value. Ethertypes are described in [IEEE 802].

d) Slow protocol subtype: Assigned by the IEEE and fixed with a value of 0x0A.

e) ITU OUI: Organizational unique identifier assigned by the IEEE registration authority.

f) The ITU subtype is assigned by ITU-T. The value of 00-01 applies to all usage defined in this Recommendation.

g) Version: The four-bit field indicates the version of ITU-T OSSP frame format. This field shall contain the value 0x1 to claim compliance with version 1 of this protocol.

h) Event flag: This bit distinguishes the critical, time-sensitive behaviour of the ESMC event PDU from the ESMC Information PDU. A value of 1 indicates an event PDU, a value of 0 indicates an information PDU.

NOTE 1 – The behaviour of the event PDU is similar to the critical event defined for Ethernet OAM in clause 57 of [IEEE 802.3]. Event messages need to meet processing times defined in [ITU-T G.781].

i) Reserved for future standardization (27 bits). These fields are set to all zero at the transmitter and are ignored by the receiver.

j) Data and padding: This field contains data and necessary padding to achieve the minimum frame size of 64 bytes. The PDU must be an integral number of bytes (octets). Padding characters are set to all zero and are ignored by receivers.

NOTE 2 – The recommended maximum size for the ESMC PDU is 128 bytes as per Annex 57B of [IEEE 802.3]. However, PDU sizes greater than 128 bytes may be permitted.

k) FCS: Four-byte frame check sequence as defined in clause 4 of [IEEE 802.3].

11.3.1.2 QL TLV format

The format of the QL data is indicated in Table 11-4 below; the format used for both information and event messages. The length field encompasses the entire TLV, including the type and length fields. This follows the TLV convention described in clause 57.5.2.1 of [IEEE 802.3].

Table 11-4 – QL TLV format

Octet number	Size/bits	Field
1	8 bits	Type: 0x01
2-3	16 bits	Length: 00-04
4	bits 7:4 (Note)	0x0 (unused)
	bits 3:0	SSM code
NOTE – Bit 7 of octet 4 is the most significant bit. The least significant nibble, bit 3 to bit 0 (bits 3:0) contains the four-bit SSM code.		

To allow for potential hardware implementations, the QL TLV is always sent as the first TLV in the data/padding field. This means that the QL indication always remains fixed in the PDU. All additional TLVs (e.g., the extended QL TLV) must occur after the QL TLV and with no padding between TLVs. Any padding must occur after the last TLV.

11.3.1.3 Extended QL TLV format

To support new clocks and added functionality, an extended QL TLV is defined in Table 11-5. This TLV is 20 bytes in length and supports the information contained in the specified fields. The new clock quality levels are defined in Table 11-6. This supports new clock types as well as carrying new information.

NOTE 1 – In previous versions of this Recommendation, Octets 4-20 in Table 11-5 were referred to as the "Extended SSM". This term is no longer used in this Recommendation.

NOTE 2 – These tables may be updated to include other clocks as they are developed.

Table 11-5 – Extended QL TLV

Octet number	Size/bits	Field
1	8 bits	Type: 0x02
2-3	16 bits	Length: 0x0014
4	8 bits	Enhanced SSM code (see Table 11-6)
5-12	64 bits	SyncE clockIdentity of the originator of the extended QL TLV (Note 1)
13	8 bits	Flag (Note 2)
14	8 bits	Number of cascaded eEECs from the nearest SSU/PRC/ePRC
15	8 bits	Number of cascaded EECs from the nearest SSU/PRC/ePRC
16-20	40 bits	Reserved for future use
NOTE 1 – The synchronous Ethernet (SyncE) clockIdentity is formatted as per this clause. The originator of the extended QL TLV refers to the clock that starts or restarts the counts of cascaded clocks within the TLV. If the count of clocks is started or restarted in the middle of the chain, the partial chain bit is set to 1 (see Note 2 and clause 11.3.1.4). NOTE 2 – Bit 0 means mixed EEC/eEEC (i.e., 1 if at least one of the clocks is not an eEEC; 0 if all clocks are eEEC); bit 1 means partial chain (i.e., 1, if the TLV has been generated in the middle of the chain and the count of the EEC/eEEC is incomplete); bits 2-7 reserved for future use. See also clause 11.3.1.4.		

Table 11-6 – Enhanced SSM codes for SyncE

Clock	Quality level	Enhanced SSM code
EEC1	QL-EEC1	0xFF
EEC2	QL-EEC2	0xFF
Other clock types contained in [ITU-T G.781] (Note)	QL message (refer to the QL TLV) (Note)	0xFF
PRTC	QL-PRTC	0x20
ePRTC	QL-ePRTC	0x21
eEEC	QL-eEEC	0x22
ePRC	QL-ePRC	0x23
NOTE – Tables 11-~~8~~ 7 and 11-~~9~~ 8 illustrate the full set of clock types from [ITU-T G.781].		

The SyncE clockIdentity should be generated according to the following rules:

a) If the SyncE node supports the extended QL TLV but not a PTP clock, the SyncE clockIdentity can be constructed from an OUI, MAC address – medium (MA-M) or MAC address – small (MA-S), e.g.,

   i) If the SyncE clockIdentity is constructed using an OUI for the initial 3 octets, the organization owning the OUI shall ensure that the remaining 5 octets of the EUI-64 are unique within the scope of SyncE clockIdentity values assigned by the organization;

   ii) If the SyncE clockIdentity is constructed using an MA-M for the initial 3.5 octets, the organization owning the MA-M shall ensure that the remaining 4.5 octets of the EUI-64 are unique within the scope of SyncE clockIdentity values assigned by the organization;

   iii) If the SyncE clockIdentity is constructed using an MA-S for the initial 4.5 octets, the organization owning the MA-S shall ensure that the remaining 3.5 octets of the EUI-64 are unique within the scope of SyncE clockIdentity values assigned by the organization.

b) If the SyncE node supports the extended QL TLV and a PTP clock based on [b-IEEE 1588], and

   i) if the PTP clockIdentity is constructed using an OUI for the initial 3 octets, and the remaining 5 octets are uniquely assigned by the organization, the SyncE clock can use this PTP clockIdentity as SyncE clockIdentity, or use the rule of (a) above to generate a separate SyncE clockIdentity; otherwise

   ii) if the PTP clockIdentity is constructed from EUI-48, or Non-IEEE EUI-64, the SyncE clock should use the rule of (a) above to generate a SyncE clockIdentity.

c) If the SyncE node supports extended QL TLV and a PTP clock and the PTP clockIdentity is constructed:

   i) using an OUI for the initial 3 octets, and the remaining 5 octets are uniquely assigned by the organization; or

   ii) using an MA-M for the initial 3.5 octets, and the remaining 4.5 octets are uniquely assigned by the organization; or

   iii) using an MA-S for the initial 4.5 octets, and the remaining 3.5 octets are unique assigned by the organization,

the SyncE clock can use this PTP clockIdentity as SyncE clockIdentity, or use the rule of a) above to generate a separate SyncE clockIdentity.

11.3.1.4 Interworking between different SyncE generations

While the extended QL TLV was developed for use with the eEEC, the basic mechanism could be applied in the future to the older EEC. This results in three possible combinations of clocks that need to be considered; eEEC with extended QL TLV support, EEC with no extended QL TLV support, and EEC with extended QL TLV support.

In case of already deployed nodes not supporting the extended QL TLV, interworking between different generations of synchronous Ethernet is achieved by the fact that a network element must discard and not forward upon reception any TLV within the ESMC PDU that it does not recognize.

The extended QL TLV allows the count of the number of cascaded eEEC and EEC clocks. If a clock not supporting the extended QL TLV is present within a chain of clocks, discarding the TLV, as noted above, will result in incomplete counts. The extended QL TLV specifies a flag to allow clocks supporting enhanced ESMC messages to have the ability to report the presence of clocks that may have discarded TLVs.

As an example, in case of a chain of eEECs, bit 0 and bit 1 will both be "0" at the output of the chain indicating that the syncE chain is fully based on eEECs, and the count of clocks is complete.

In case of an intermediate EEC, not able to process the extended QL TLV, the EEC shall drop the TLV. At the next eEEC in the SyncE chain, the TLV will be added with both bit 0 and bit 1 set to "1" to indicate that the SyncE chain is not fully based on eEEC, and the count of clocks is not complete.

However, in case of an intermediate EEC that is able to process the extended QL TLV, at the output of that EEC bit 0 is set to 1 to indicate that the SyncE chain includes a mix of EEC and eEEC, and bit 1 is set ~~to 0 to indicate that the count of the clocks in the chain is complete~~to the value it receives.

11.3.2 Protocol behaviour

The ESMC PDU contains the QL TLV for synchronous Ethernet. Synchronization source selection using SSM is defined in [ITU-T G.781]. [ITU-T G.781] is applicable to both SDH and synchronous Ethernet. The protocols for carrying SSM differ for SDH and synchronous Ethernet. Pre-processing in the appropriate atomic functions provides a uniform interface to the synchronization processing algorithm. The protocol described within this clause adheres to the requirements for slow protocols given in Annex 57B of [IEEE 802.3].

The SSM code contained in the QL TLV represents the free-run accuracy of the clock that is currently the clock source of the synchronization trail. Specific bounds on the processing times of messages are defined in [ITU-T G.781].

NOTE – The processing times are specified for ideal conditions. There may be cases where these processing times are not met.

When a NE is operating in the QL-enabled mode, the protocol generation and reception must meet the criteria below in clauses 11.3.2.1 and 11.3.2.2, respectively. The synchronization selection function in Annex A of [ITU-T G.781] has been modelled using SDL descriptors. The critical aspects of the algorithm are based on the input QL of each of p inputs (i.e., QL[p] in [ITU-T G.781]). The output QL, QL_out, is the SSM code that is to be transmitted on output ports of the NE. [ITU-T G.781] describes cases where DNU is applied instead of the active QL. Annex A of [ITU-T G.781] is normative, it describes the NE behaviour. It does not necessarily mandate a specific implementation.

Within this Recommendation, QL states are used to describe the protocol behaviour. This is the QL state that would be present at the input to the synchronization selection algorithm at the SD_CI interface.

Generation is based on the QL_out state, while reception is based on the QL[p] state. It is assumed that these states are maintained within appropriate atomic functions for synchronous Ethernet or SDH (e.g., the ETY/SD or MS/SD functions, respectively).

11.3.2.1 QL generation

An ESMC information PDU, containing the current QL used by the system clock selection algorithm, is generated once per second.

In the case of a change in the QL level, an ESMC event PDU (i.e., the event flag is set) containing the new QL TLV is generated upon detection of the QL change, subject to message transition and processing times given in [ITU-T G.781].

In no case can more than ten ESMC PDUs (information and/or event) be generated in any one-second period as per Annex 57B of [IEEE 802.3].

NOTE – The ESMC PDU is only one slow protocol PDU that may be present in a system. [IEEE 802.3] places limits on the total number of slow protocols, each subject to a maximum transmission of ten frames per second. Implementations that implement multiple slow protocols should consider the time-sensitive nature of the event message type.

The SSM codes are defined for the different regional options.

For option 1 networks, if a clock supports only the QL TLV, it should set the SSM code according to Table 11-7, and send the QL TLV.

If a clock in an option 1 network supports both the QL TLV and the extended QL TLV, it should set the SSM code and the enhanced SSM code according to Table 11-~~8~~7, and send both the QL TLV and the extended QL TLV. Both TLVs shall be sent in one ESMC PDU.

For option 2 networks, if a clock supports only the QL TLV, it should set the SSM code according to Table 11-8, and send the QL TLV.

If a clock in an option 2 network supports both the QL TLV and the extended QL TLV, it should set the SSM code and the enhanced SSM code according to Table 11-~~9~~8, and send both the QL TLV and the extended QL TLV. Both TLVs shall be sent in one ESMC PDU.

For option 3 networks, SSM codes and enhanced SSM codes for syncE are for further study.

Table 11-7 – SSM codes and enhanced SSM codes for SyncE in option 1 networks

Clock	Quality level	SSM code	Enhanced SSM code
PRC	QL-PRC	0010	0xFF
SSU-A	QL-SSU-A	0100	0xFF
SSU-B	QL-SSU-B	1000	0xFF
EEC1	QL-EEC1	1011	0xFF
(Note 1)	QL-DNU	1111	0xFF
PRTC	QL-PRTC	0010	0x20
ePRTC	QL-ePRTC	0010	0x21
eEEC	QL-eEEC	1011	0x22
ePRC	QL-ePRC	0010	0x23
NOTE 1 – There is no clock corresponding to this quality level. NOTE 2 – ~~When processing the SSM QL, the SSM code should be processed first, followed by the enhanced SSM code.~~ If a clock supports the processing of an enhanced SSM code, the quality level is represented by a combination of SSM code and enhanced SSM code. If the ESMC message received by the clock does not have an enhances SSM code, 0xFF is used for the enhanced SSM code of this clock.			

Table 11-8 – SSM codes and enhanced SSM codes for SyncE in option 2 networks

Clock	Quality level	SSM code	Enhanced SSM code
PRS	QL-PRS	0001	0xFF
(Note 1)	QL-STU	0000	0xFF
ST2	QL-ST2	0111	0xFF
TNC	QL-TNC	0100	0xFF
ST3E	QL-ST3E	1101	0xFF
ST3	QL-ST3	1010	0xFF
EEC2	QL-EEC2	1010	0xFF
(Note 1)	QL-PROV	1110	0xFF
(Note 1)	QL-DUS	1111	0xFF
PRTC	QL-PRTC	0001	0x20
ePRTC	QL-ePRTC	0001	0x21

Table 11-8 – SSM codes and enhanced SSM codes for SyncE in option 2 networks

Clock	Quality level	SSM code	Enhanced SSM code
eEEC	QL-eEEC	1010	0x22
ePRC	QL-ePRC	0001	0x23
NOTE 1 – There is no clock that corresponds to this quality level. NOTE 2 – If a clock supports the processing of an enhanced SSM code, the quality level is represented by a combination of SSM code and enhanced SSM code. If the ESMC message received by the clock does not have an enhances SSM code, 0xFF is used for the enhanced SSM code of this clock. ~~When processing the SSM QL, the SSM code should be processed first, followed by the enhanced SSM code.~~			

11.3.2.2 QL reception

The QL state, QL_out, is utilized by the synchronization selection algorithm described in [ITU-T G.781] (see Annex A of [ITU-T G.781]). For synchronous Ethernet, the slow protocol used for the transmission of the SSM code relies on the use of a "heart-beat" timer. ESMC information PDUs are sent periodically at a rate of one PDU per second. Lack of reception of an ESMC information PDU within a five-second period results in the SSF=true (QL=QL-FAILED in QL-Enabled mode). The synchronization reference is now subject to a wait-to-restore period as defined in [ITU-T G.781]

The default (initial) value for the QL is DNU and must only change when a valid QL TLV is received.

Upon reception of an event TLV, the QL state is changed to the new QL value, and the information timer is reset.

11.4 ESMC PDU extensions

Future extensions to the ESMC PDU are for further study. However, it is expected that future extensions will be specified in terms of a TLV format. The TLV format is indicated in Table 11-9. The size of the TLV is calculated as the total number of octets in the TLV structure. The length includes the type and length fields. Padding of data is required to ensure that the TLV contains an integral number of octets.

NOTE – Two bytes are used to represent the length field. The suggested maximum size of a slow protocol PDU is 128 bytes as per Annex 57B of [IEEE 802.3]. However, slow protocol PDU lengths greater than 128 bytes are permissible.

Details of usage are for further study.

Table 11-9 – TLV structure

1 byte	Type
2 bytes	Length (octets)
N bytes	Data plus padding

11.5 Interworking with existing synchronization networks

See clause A.5 of [ITU-T G.8261].

11.6 SSM for clocks with enhanced holdover

For NEs with EEC clocks, there may be cases where the internal holdover quality of the clock is better than what is specified in [ITU-T G.8262]. In this case, if an SSU is not present in the remainder of the timing chain to provide improved holdover, it may be advantageous for the NE to locally reject the input when the incoming QL is equal to EEC and thus rely on the holdover of its internal clock to

drive downstream clocks rather than continue to track the input. This may provide better performance to downstream clocks for certain applications.

This behaviour could be achieved by proper provisioning of the QL of the node. In cases where the holdover behaviour is consistent with existing clocks, the appropriate QL value (e.g., SSU-A or SSU-B) should be used, consistent with [ITU-T G.781].

Alternatively, similar behaviour could also be achieved by modifying the incoming QL (e.g., from QL=EEC to QL=DNU) under certain circumstances.

With either method, the modified behaviour of the NE has to be carefully configured to be consistent with the operator's overall network synchronization plan.

12 Use of synchronous Ethernet in a multi-operator context

There may be scenarios where a timing reference needs to be distributed in a multi-operator context. This situation corresponds to a case where the timing signal of an operator is carried over the network of another operator. This timing signal may be sent towards end equipment which may require a timing reference (e.g., a base station (BS)). See Figure 12-1.

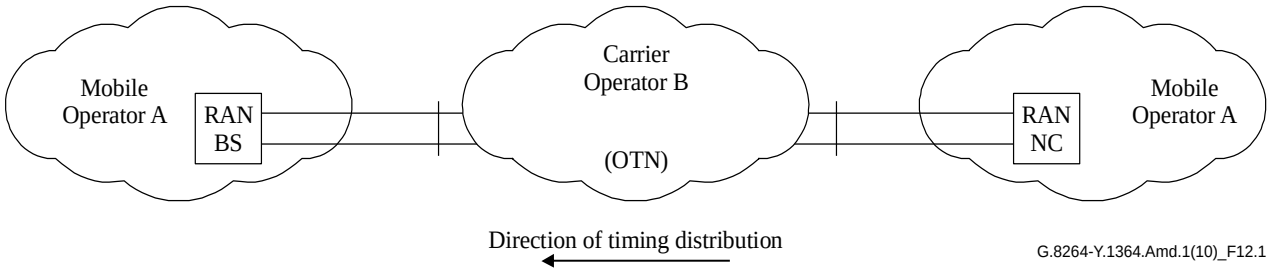

Figure 12-1 – Illustration of the multi-operator context

The terms "carrier operator" and "mobile operator" will be used in the following descriptions in order to illustrate the discussion with a realistic case; however, the intention is not to restrict the discussion to this unique case, and the depicted cases should be considered as possibly more generic.

In the case where the timing is carried by synchronous Ethernet, two different approaches involving the carrier operator's network may be envisaged in order to deliver a timing reference to the end equipment, depending if the synchronous Ethernet client signal is transported transparently or not from the timing perspective.

Indeed, depending on the type of Ethernet managed service that is proposed by the carrier operator, a synchronous Ethernet signal from a mobile operator may not be transparently transported in terms of its timing reference (for instance, when the physical layer of the carrier network is Ethernet). In such a situation of non-timing transparency, the Ethernet client signal at the output of the Ethernet managed service is not carrying the original synchronous Ethernet timing reference.

In the case of an OTN network, timing transparency is supported in [ITU-T G.709]. For example, the use of the TTT+GMP mapping specified in [ITU-T G.709] enables a timing transparent transport of 1 Gigabit synchronous Ethernet client signals through OTN.

The case of a timing transparent Ethernet managed service is discussed in clause 12.1, and the case of a non-timing transparent Ethernet managed service is discussed in clause 12.2.

12.1 Timing transparent transport of synchronous Ethernet client signals

This first approach assumes that the timing information of synchronous Ethernet client signals can be transported transparently over the carrier operator's network. This may be achieved, for instance, using an OTN network, with an appropriate timing transparent mapping. As mentioned, an example

is the transport of 1000Base-X client signal using a TTT+GMP mapping, as defined in [ITU-T G.709]. Such mapping allows transporting the client signal bit stream over the transport network, including the timing and ESMC message.

The carrier operator maps and unmaps the synchronous Ethernet client signal and carries the timing signal and ESMC messages transparently over the OTN transport network (the OTN network is unaware of the presence of timing and ESMC messages in the client signal). The entire connection over the carrier operator is based on OTN equipment. This scenario is illustrated in Figure 12-2.

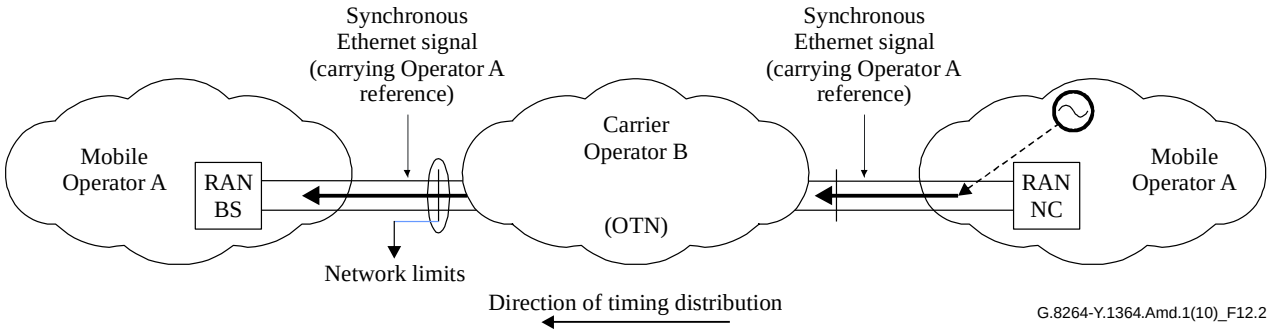

Figure 12-2 – Illustration of a timing transparent transport of the synchronous Ethernet client signals in the multi-operator context

In this scenario:

– the synchronous Ethernet signal generated by the mobile operator carries the timing reference of the mobile operator, including ESMC messages;

– the synchronous Ethernet signal is carried transparently over the carrier operator's network (the bit stream is transparently transported including the timing and ESMC messages);

– the mobile operator receives and uses its own timing reference, including ESMC messages, which have been carried transparently over the carrier operator's network to synchronize end equipment in the mobile operator's network.

It has to be noted that this approach is fully in line with the traditional case of a timing transparent transport of TDM signals (e.g., PDH transported in PDH network, SDH transported in OTN).

The network limits at the output of the carrier operator's network corresponds to the synchronous Ethernet network limits, as defined in clause 9.2.1 of [ITU-T G.8261].

12.2 Synchronization service provided by the carrier operator based on an interface providing a physical timing reference (generation of synchronous Ethernet interface)

This second approach covers the case where the carrier operator's network is a packet network (e.g., Ethernet) and is not transparent to the physical layer timing signals, such as synchronous Ethernet. For instance, this may be the case when Ethernet private line (EPL) and Ethernet virtual private line (EVPL) services, as defined in [b-ITU-T G.8011], are used (i.e., all Ethernet frames are transported from ingress to egress on the carrier operator's network, but the timing is not transported).

The carrier operator may, however, offer to deliver a timing reference to the mobile operator. For instance, the synchronous Ethernet signal delivered at the output of the carrier operator's network may be generated with the carrier operator's timing reference. This case implies an agreement between the two operators. This scenario is illustrated in Figure 12-3.

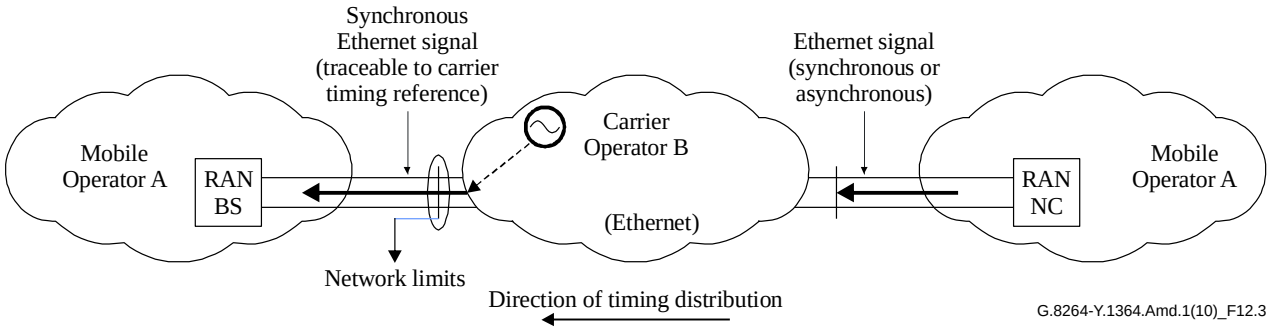

Figure 12-3 – Illustration of a synchronous Ethernet synchronization service in the multi-operator context

In this scenario:

– the mobile operator subscribes to a specific synchronization service (which could be part of the mobile backhaul connectivity offer);

– the mobile operator sends an Ethernet signal carrying its traffic, but the timing reference of the source cannot be carried over the carrier network. ESMC messages from the mobile operator are not passed through the carrier operator's network. In this case, the input Ethernet signal does not need to be a synchronous Ethernet signal;

– the carrier operator provides the timing, including the ESMC, at the edge of the carrier network resulting in the synchronous Ethernet signal being traceable to the clock within the carrier network. This approach assumes that the ESMC messages generated by the carrier operator can be inserted in the output synchronous Ethernet signal together with the mobile operator's data traffic. The specific cases when ESMC insertion may not be properly processed (e.g., bit transparent services) are for further study;

– equipment within the mobile operator uses the timing reference and ESMC messages delivered by the carrier operator's network.

It has to be noted that this second approach is only applicable in case the end equipment requires an absolute timing reference (e.g., primary reference clock (PRC) traceability). For instance, in order to deliver a timing reference to a BS, instead of sending the timing reference of the mobile operator, traceable to coordinated universal time (UTC), to the BS, the carrier operator's timing reference, also traceable to UTC, may be used.

For TDM end applications traceable to a PRC/enhanced primary reference clock (ePRC) requiring the control of slip rate, it has to be mentioned that this situation can be considered similar to the pseudo-synchronous mode defined in [b-ITU-T G.810] that is sometimes used within the same operator domain (e.g., when several PRC/ePRCs are used), and that still ensures that a potential TDM slip rate is controlled according to [ITU-T G.822].

The network limits at the output of the carrier operator's network should correspond to the synchronous Ethernet network limits, as defined in clause 9.2.1 of [ITU-T G.8261].

In this second approach, the synchronous Ethernet signal at the output of the carrier operator's network must carry an SSM value via the ESMC. The information contained within the ESMC is part of the agreement between the operators.

13 Synchronization management aspects

For further study.

Annex A

Reference source selection mechanism

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

Synchronous Ethernet equipment will require a reference source selection mechanism to provide traceability to upstream elements and ultimately the PRC (or ePRC) with respect to frequency.

A.1 Requirements

The selection mechanism controls the physical timing flows within the equipment.

The selection mechanism must be able to select:

– an appropriate external reference source;

– an appropriate traffic reference source;

– internal clock (i.e., local oscillator).

A reference derived from an Ethernet traffic source that is not a synchronous Ethernet interface shall not be selected.

A.2 Inputs

The node synchronization source can be:

– an external input reference;

– a recovered clock reference from the line.

A.3 Internal oscillator

This provides filtering and holdover.

A.4 Internal physical timing flows – Frequency ETY

A number of internal physical timing flows will be required to synchronize the ETY layer (Ethernet PHY).

A.5 Selection mechanism

Synchronous Ethernet equipment shall support a selection mechanism that allows synchronization to be derived from the line (i.e., traffic-carrying interfaces), from external synchronization interfaces (i.e., provided by co-located equipment) or internally from the EEC. These will be supported by the SSM message set. Figure A.1 shows a high-level representation of a synchronization sub-system selection mechanism for synchronous Ethernet equipment.

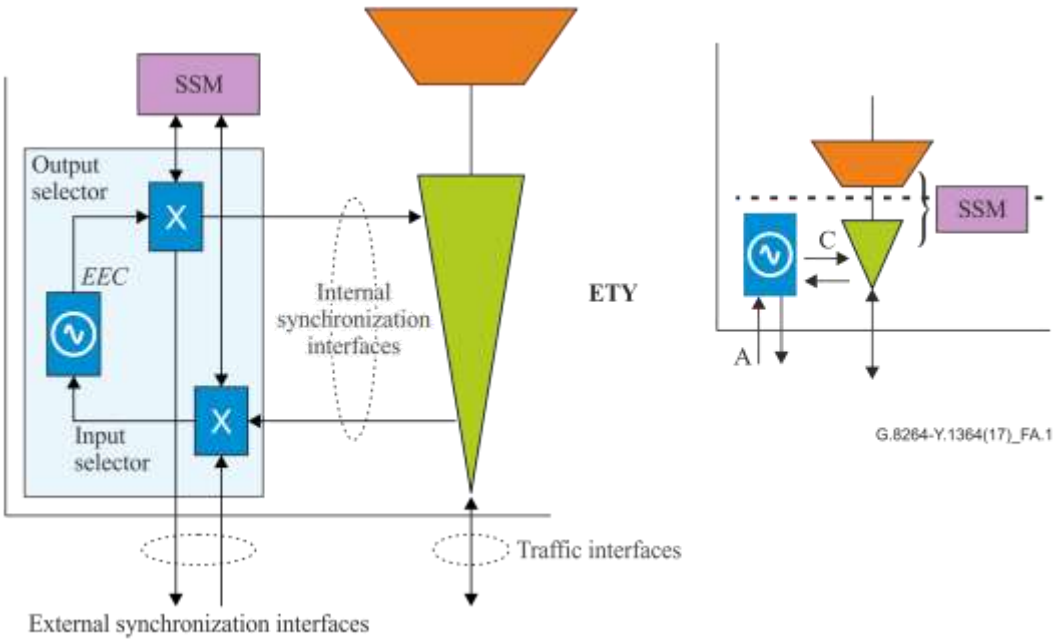

Figure A.1 – Synchronous Ethernet equipment – High-level representation of synchronization sub-system selection mechanism

The EEC within the internal synchronization sub-system shall comply with [ITU-T G.8262].

The synchronous Ethernet equipment shall have the ability to recover synchronization from the synchronization inputs of either traffic interfaces via the "internal synchronization interfaces" and/or "external synchronization interfaces". These will be injected into an internal synchronization sub-system.

The internal synchronization sub-system shall provide the necessary filtering and holdover performance and shall perform any synchronization messaging functionality.

The internal synchronization sub-system shall be able to select an alternate synchronization source through the use of priority tables and synchronization status messaging.

The internal synchronization sub-system shall make use of the SSM to determine priority and clock traceability.

The internal synchronization sub-system shall provide clocks of the appropriate rates (internal synchronization interfaces) to lock the ETY of the traffic interface.

A.6 Synchronization status message selection

SSMs are required to allow the downstream element that requires synchronization to know the quality of the upstream clock.

The synchronization message shall be "pushed" from device to device that supports synchronous Ethernet. At each device that supports synchronous Ethernet, the message shall be processed and acted upon. The message set shall then be remade and passed to the next downstream element.

The synchronization sub-system shall be able to select an alternate source based on priority and SSM.

A.7 Hybrid equipment selection function

Figure A.2 shows the equivalent selection mechanism of an SDH synchronous equipment timing source (SETS) function that has been adapted to hybrid SDH/synchronous Ethernet equipment having synchronous Ethernet and SDH interfaces. ETY and STM-N input (TE and T1) and output (T0) represent the various Ethernet traffic interfaces (e.g., 100Base-TX, 1000Base-SX) and SDH traffic

interfaces. The synchronous equipment timing generator (SETG) has characteristics defined in [ITU-T G.8262] for synchronous Ethernet and in [ITU-T G.813] and [ITU-T G.812] for SDH. Also note that, in North American networks, the T4 interface provides network timing to a building integrated timing supply (BITS)/SSU only. Selection of line interfaces (e.g., TE or T1 in Figure A.2) is only provided via selector A. Selector C can only select the output from selector A. T4 is not filtered by the SETG, as filtering is done by the BITS/SSU.

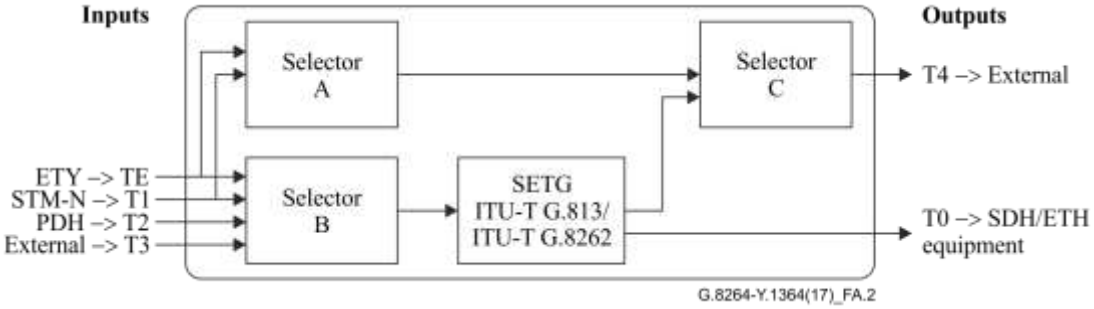

Figure A.2 – Hybrid SDH/synchronous Ethernet SETS function

Appendix I

Examples of timing flows

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

Figure I.1 is a representative example designed to bring the various timing flows together using a simple TDM circuit over an Ethernet link.

A PDH bit stream enters equipment [A]. Between equipment [A] and equipment [B], a logical "service" timing flow exists between the first adaptation points. Any offsets injected into the TDM/Ethernet function at equipment [A] must be maintained at the output at equipment [B].

To facilitate the timing flow, and ensure that the order integrity is maintained, some form of timestamp will be applied, such as RTP. This is a message flow. Between equipment [A] and equipment [B], a logical message timing flow exists that supports the service flow.

At the physical layer, equipment [A] is physically connected to equipment [B] via trail termination points. This connection provides the link or physical medium over which the raw bandwidth is carried. The upper layer service is packetized and carried over this link. A physical timing flow exists between equipment [A] and equipment [B], with the network clock forming part of the line code at the ETY layer.

Within equipment [A] and equipment [B], a number of physical point-to-point timing flows also exist to support the adaptation and packetization functions. These flows will be a frequency traceable to the embedded clock.

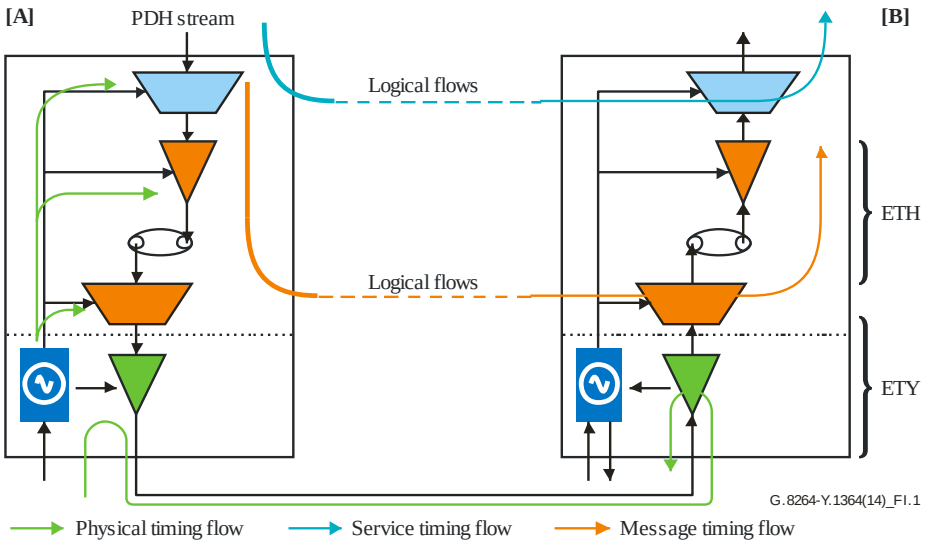

Figure I.1 – Example of flows

Figure I.2 presents the general model from [ITU-T G.8010] extended to show two unidirectional ETH flows necessary to support bidirectional TDM circuit emulation. This figure adds TDM to ETH adaptation functions that would be necessary to support TDM over Ethernet, as well as the physical layer (ETY layer). Also shown are the approximate functions (in the dashed box) that are currently being discussed in Appendix I of [ITU-T G.8261].

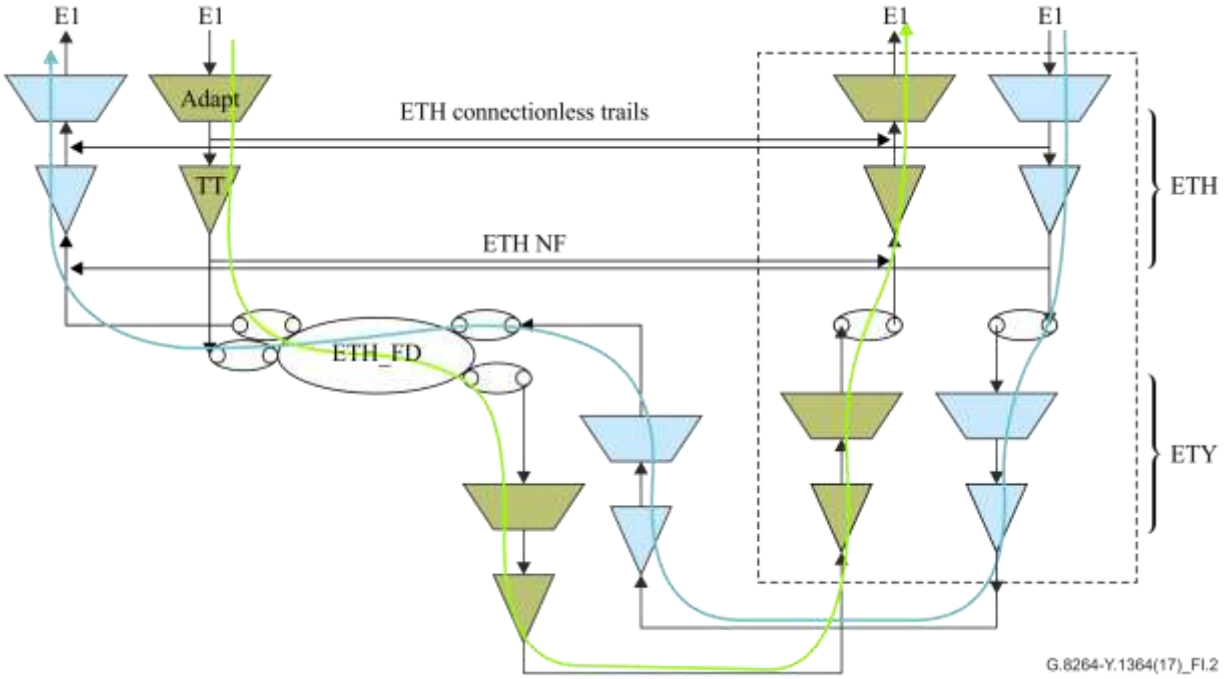

Figure I.2 – ITU-T G.8010 Ethernet network architecture showing circuit emulation and timing trails

Figure I.3 further extends this model to include intermediate switches and possible timing distribution within each switch. Only one direction is shown in this figure. The timing configuration, in this case, shows one IWF being timed externally, while the other is timed via the incoming physical layer link. If the reference clocks are traceable to PRC/ePRC, then ultimately the same clock (i.e., UTC) is available at both IWF functions.

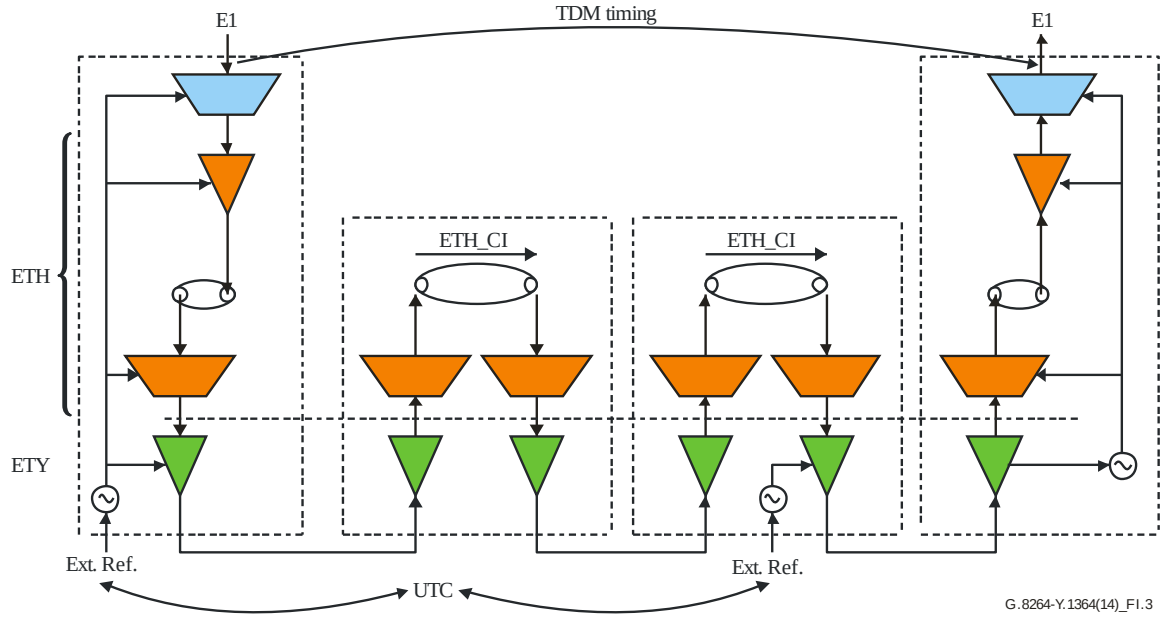

Figure I.3 – TDM over Ethernet network

Appendix II

Functional models based on ITU-T G.805 and ITU-T G.809

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

II.1 Background

This appendix provides the current view on the development of synchronization modelling using some of the basic concepts provided in [ITU-T G.805].

The architecture of Ethernet networks is specified in [ITU-T G.8010], which defines the architecture in [ITU-T G.805] and [ITU-T G.809] terms. [ITU-T G.805] and [ITU-T G.809] are modelling methods developed by ITU-T that allow formal specification of network architectures and equipment.

[ITU-T G.8261] includes a brief description of the IWF that is necessary to carry TDM payloads over packet-based networks. This appendix provides an example of the components that may be needed to carry emulated PDH services over packet networks. The description of the IWF in [ITU-T G.8261] does not describe the IWF in terms of current [ITU-T G.805] modelling constructs. The reason for this is that certain aspects related to synchronization cannot be described in terms of [ITU-T G.805] modelling methods. Extensions to the [ITU-T G.805] models are needed in this regard. This appendix provides preliminary functional models.

The IWF described in Figure B.4 of [ITU-T G.8261] contains a number of key elements necessary to adapt TDM signals to packet-based transport.

These functions include:

– TDM-to-packet conversion;

– packet-to-TDM conversion;

– packet-related functions (e.g., addition of overhead);

– physical layer transport.

Critical to synchronization of the IWF are various clocks. For example:

– TDM clock recovery and generation;

– physical layer clock recovery;

– packet-based clock recovery.

In the case of packet-based clock recovery, [ITU-T G.8261] describes two general methods: differential and adaptive.

II.2 Application of ITU-T G.805 to the IWF

[ITU-T G.805] contains a number of architectural constructs that allow specification of layer networks. A key property of [ITU-T G.805] is the notion of client-server relationships within a network architecture. A specific network may have multiple layers, each layer interacting in a client-server relationship. Examples of layer networks include SDH, OTN and Ethernet. In the case of SDH, the three layers are path layer, MS layer and RS layer. The path layer is a client of the multiplex layer; the multiplex layer is a client of the regenerator layer. In the case of Ethernet, [ITU-T G.8010] defines two layers, the ETH layer and the ETY layer. The ETH layer is analogous to layer 2 in the open systems interconnection (OSI) reference model (i.e., the data link layer) and provides packet type functions. The ETY layer is analogous the OSI physical layer (i.e., layer 1).

[ITU-T G.805] describes functional blocks that provide the ability to describe the properties of the individual network layers. The two key functional blocks are adaptation functions and trail termination functions. Interaction between layers is provided by adaptation functions. Trail termination functions add necessary overhead to carry the signal through the server layer network. A

client layer network is carried over a server layer network by adapting the client to the server using an adaptation function. The information that is carried over a given layer is termed the characteristic information (CI). For further information, see [ITU-T G.805].

With regard to the CES IWF, and with application to Ethernet ETH and ETY layers, Figure B.4 of [ITU-T G.8261] contains packet-layer and physical-layer functions, and thus both the ETH and ETY layers are implemented within the IWF. The PDH-to-packet conversion is not part of the Ethernet layers, but can be considered as an adaptation function in terms of [ITU-T G.805]. The basic IWF function in the PDH-to-packet direction (PDH input to IWF) can be viewed functionally as in Figure II.1 (a) and the packet-to-TDM direction (PDH output) can be viewed as in Figure II.1 (b).

NOTE – Some clock components of the IWF are not explicitly shown in this figure (e.g., clocks, clock reference selectors), while others may be contained within specific functions. For example, PDH clock recovery may be considered as part of the PDH-to-packet layer adaptation function as it is related to adapting client layer clock information to the underlying server layer (see clause II.3, below). In addition, the functional blocks contained in Figure II.1 are described in ways that do not restrict implementation and may be applied to various equipment topologies.

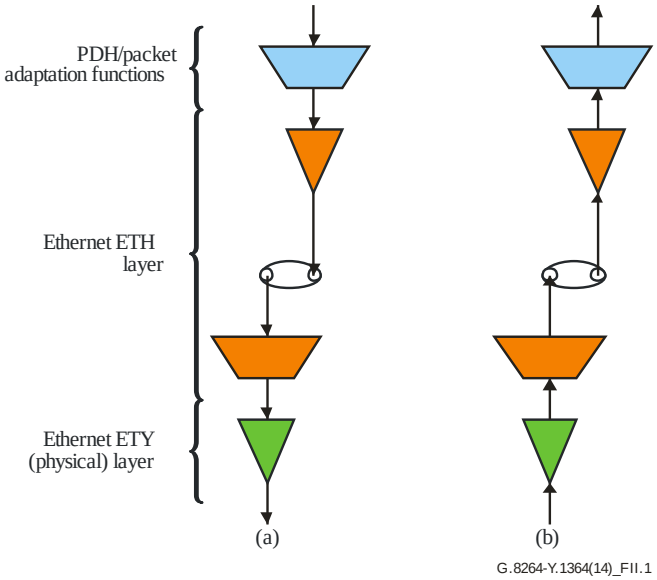

Figure II.1 – Functional blocks within CES IWF

II.3 Timing information transported over layer networks

The layer network modelling methodology allows the transport of information from a client-layer over a server-layer network. The information that is transported is called the characteristic information (CI). The CI is defined for a specific layer network and will vary for different layer networks. For example, the CI of a PDH signal consists of the data and clock information.

With respect to clock information, the PDH layer network and the ETY layer network have timing information as part of the CI, while the ETH layer does not. The CI of a PDH signal into the IWF consists of data and clock information (the service clock). The function of the IWF is to transport this data and clock information.

As noted above, adaptation functions are used to adapt the client information to be carried over a server-layer network. In this case, the CI of the client-layer network is now called adapted information (AI). In all cases, server-layer networks can transport the data portion of the client CI, but not all server-layer networks can inherently transport timing information. In such a case, where timing is required to be transported, alternative means of providing timing are required.

With respect to packet-server layer networks, this Recommendation describes two methods that are intended to allow timing information of the client-layer PDH signal to be carried over a packet-based

server-layer network. Clause 8 of [ITU-T G.8261] describes differential and adaptive mechanisms to accomplish this.

II.4 Functional model of Ethernet physical layer timing

Figure B.4 of [ITU-T G.8261] shows that the IWF may be timed via the "packet physical interface". In terms of the Ethernet architecture model, only the ETY trail termination function and the ETH/ETY adaptation function are used. For a point-to-point link, the functional model is shown in Figure II.2. The timing flow is shown in this figure. Timing to the ETH/ETY adaptation function may be either from an external source or from an internal free-running oscillator.

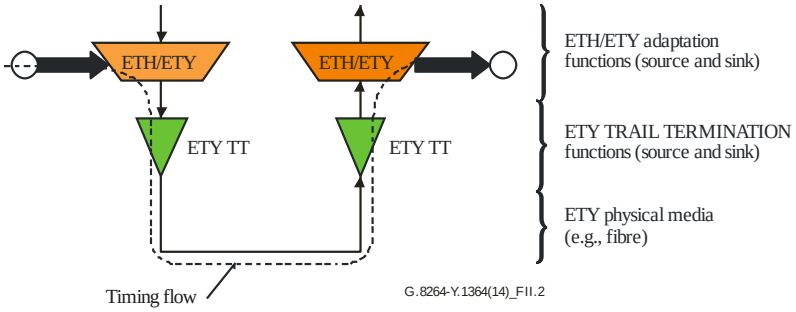

Figure II.2 – Functional model for Ethernet timing (synchronous Ethernet PHY)

Figure II.3 provides an example of how physical layer timing may time a sink PDH/ETH adaptation function.

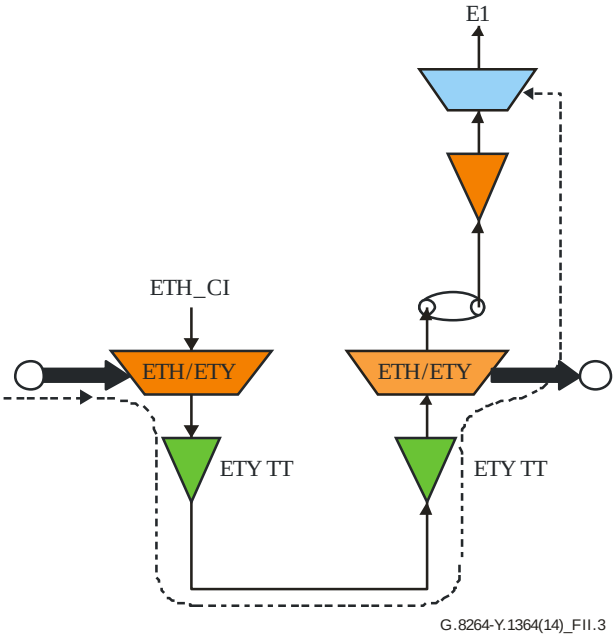

Figure II.3 – Example of using physical layer timing to provide timing to an ETH/PDH adaptation function

II.5 Functional model for differential and adaptive methods

Differential and adaptive mechanisms to transfer timing based on packet methods are described in this Recommendation. In both cases, these functions reside in the PDH/ETH adaptation functions (see Figure II.1). The main difference between these two techniques is that the differential method requires a timing reference to be provided to both the sink and the source PDH/ETH function. Adaptive methods are generally based on the average packet reception rate on the sink IWF (usually

accomplished either by measuring packets inter-arrival time or monitoring buffer fill level; some adaptive clock recovery mechanisms may also use timestamps) and thus do not need to be supplied with an external reference. The functional models for differential and adaptive methods are shown in Figures II.4 and II.5, respectively.

NOTE – In this appendix, two separate functions are defined for differential and adaptive methods to allow implementation flexibility.

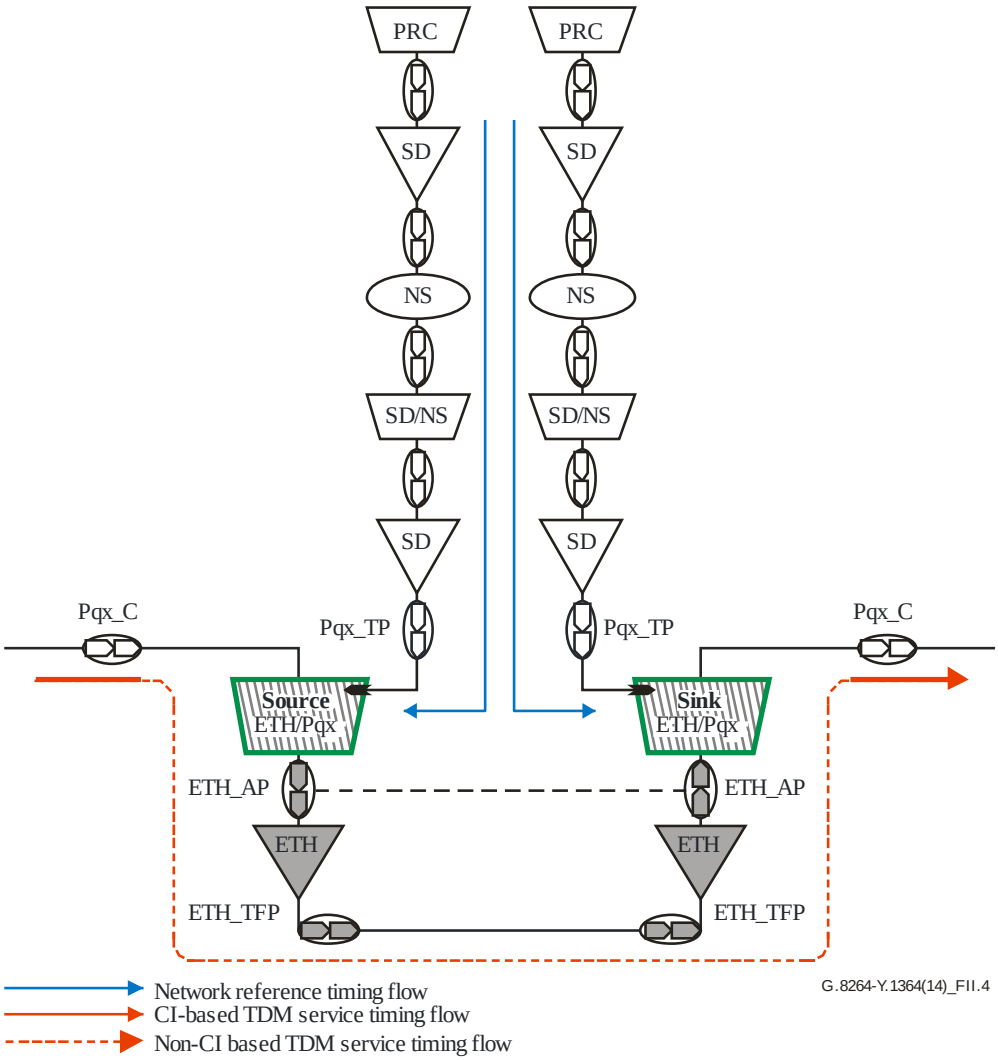

Figure II.4 – Functional models for differential timing

In the case of differential mode, both source and sink IWFs (ETH/Pqx adaptation functions) are fed with a PRC/ePRC traceable reference clock (blue timing flows). At the source IWF, the difference between the timing of the service (solid red timing flow) and the external reference is encoded in the form of timestamps. This information is transferred over the Ethernet network (dashed red timing flow). At the sink IWF, the timestamps together with the external reference are used to recreate the service clock (solid red timing flow). Hence, the same reference (traceable to PRC/ePRC) is required at both ends.

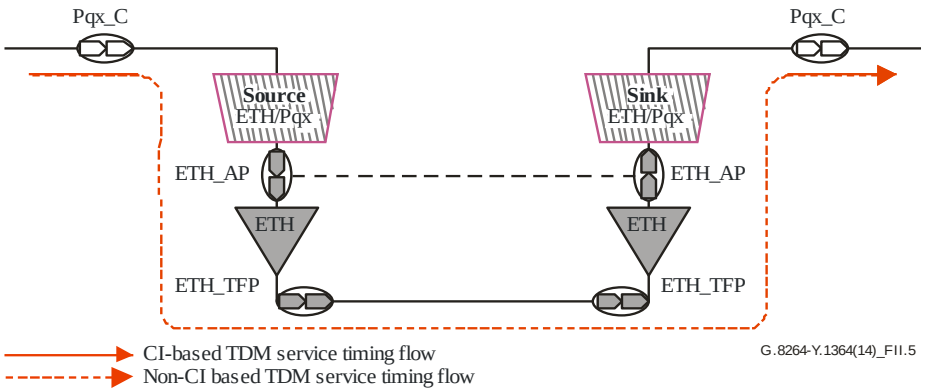

Figure II.5 – Functional models for adaptive timing

In the case of adaptive mode, the clock recovery at the sync end is based on the average packet reception rate on the sink IWF, usually accomplished either by measuring packet inter-arrival time or monitoring buffer fill level (some adaptive clock recovery mechanisms may also use timestamps). In this timing distribution mode, the use of an external reference is not required.

Details of adaptive and differential methods functions are for further study.

Bibliography

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

[b-ITU-T G.8011] Recommendation ITU-T G.8011.1/Y.1307.1 (2016), *Ethernet service characteristics*.

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

[b-IETF RFC 1305] IETF RFC 1305 (1992), *Network Time Protocol (Version 3) Specification, Implementation and Analysis*.

[b-IETF RFC 3550] IETF RFC 3550 (2003), *RTP: A Transport Protocol for Real-Time Applications*.

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