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Packet over Transport aspects – Quality and availability targets

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

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Architecture and requirements for packet-based frequency delivery

Recommendation ITU-T G.8265/Y.1365

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Recommendation ITU-T G.8265/Y.1365

Architecture and requirements for packet-based frequency delivery

Summary

Recommendation ITU-T G.8265/Y.1365 describes the architecture and requirements for packet-based frequency distribution in telecom networks. Examples of packet-based frequency distribution include the network time protocol (NTP) and IEEE-1588-2008, briefly described here. Details necessary to utilize IEEE-1588-2008 in a manner consistent with the architecture are defined in other Recommendations.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.8265/Y.1365	2010-10-07	15

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

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

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

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

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Architecture and requirements for packet-based frequency delivery

1 Scope

This Recommendation describes the general architecture of frequency distribution using packet-based methods. This version of the Recommendation focuses on the delivery of frequency using methods such as NTP or the precision time protocol (PTP) [IEEE 1588]. The requirements and architecture form a base for the specification of other functionality needed to achieve packet-based frequency distribution in a carrier environment. The architecture described covers the case where protocol interaction is at the end points of the network only, between a packet master clock and a packet slave clock. Details of requirements for other architectures involving devices that participate between the packet master and packet slave clocks are for further study.

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.8260] Recommendation ITU-T G.8260 (2010), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8261] Recommendation ITU-T G.8261/Y.1361 (2008), *Timing and synchronization aspects in packet networks*.

[ITU-T G.8264] Recommendation ITU-T G.8264 (2008), *Distribution of timing information through packet networks*, plus Amendment 1 (2010).

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

[IETF RFC 5905] IETF RFC 5905 (2010), *Network Time Protocol Version 4: Protocol And Algorithms Specification*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 packet master clock [ITU-T G.8260].

3.1.2 packet slave clock [ITU-T G.8260].

3.1.3 packet timing signal [ITU-T G8260].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CDMA Code Division Multiple Access

DSL Digital Subscriber Line

EEC Ethernet Equipment Clock

GM Grand Master

GNSS Global Navigation Satellite System

LSP Label Switched Path

LTE Long Term Evolution

MINPOLL Minimum Poll interval

NTP Network Time Protocol

PDV Packet Delay Variation

PON Passive Optical Network

PRC Primary Reference Clock

PTP Precision Time Protocol

QL Quality Level

RTP Real Time Protocol

SDH Synchronous Digital Hierarchy

SEC SDH Equipment Clock

SSM Synchronization Status Message

TDM Time Division Multiplexing

VLAN Virtual Local Area Network

WIMAX Worldwide Interoperability for Microwave Access

5 Conventions

Within this Recommendation, the term PTP refers to the PTP version 2 protocol defined in [IEEE 1588]. NTP refers to network time protocol as defined in [IETF RFC 5905].

6 General introduction to packet-based frequency distribution

The modern telecom network has relied on accurate distribution of frequency in order to optimize transmission and TDM cross-connection. In contrast, packet networks and packet services are highly buffered by their nature and, as a result, do not require accurate timing for their operation. The migration towards converged packet networks on the surface leads to the belief that frequency distribution will not be required as packet network technology becomes more prevalent in the network.

While this may be true for certain services (Internet is one example), the underlying transport mechanisms that deliver these timing agnostic services may require stringent timing requirements that must be provided in the new converged network paradigm. For example, in some cases, support of circuit emulation services over a packet-based infrastructure requires the presence of a stable frequency reference to enable the service. Likewise, in wireless access technologies (e.g., GSM, LTE, WIMAX, CDMA, etc.) the air interface requirements have stringent synchronization requirements that need to be met, even though the end-user service (e.g., mobile Internet) may seemingly not require timing.

In order to enable timing distribution in packet-based networks, ITU-T has developed specification for synchronous Ethernet [ITU-T G.8261], [b-ITU-T G.8262], [ITU-T G.8264] for the physical layer frequency distribution, which is similar to what was provided by SDH. This Recommendation describes the use of packet-based mechanisms that are intended to be used to transport frequency over a packet network in the absence of physical layer timing.

6.1 Requirements for packet timing

Packet-based mechanisms for frequency distribution must meet the following requirements:

1) Mechanisms must be specified to allow interoperability between master and slave devices (clocks).
2) Mechanisms must permit consistent operation over managed wide area telecom networks.
3) Packet-based mechanisms must allow interoperation with existing SDH and synchronous Ethernet-based frequency synchronization networks.
4) Packet-based mechanisms must allow the synchronization network to be designed and configured in a fixed arrangement.
5) Protection schemes used by packet-based systems must be based on standard telecom operational practice and allow slave clocks the ability to take timing from multiple geographically separate master clocks.
6) Source (clock) selection should be consistent with existing practices for physical layer synchronization and permit source selection based on received QL and priority.
7) Packet-based mechanisms must permit the operation of existing, standards-based, security techniques to help ensure the integrity of the synchronization.

7 Architecture of packet-based frequency distribution

In contrast to physical layer synchronization, where the significant edges of a data signal define the timing content of the signal, packet-based methods rely on the transmission of dedicated "event packets". These "event packets" form the significant instants of a packet timing signal. The timing of these significant instances is precisely measured relative to a master time source, and this timing information is encoded in the form of a time-stamp which is a machine-readable representation of a specific instance of time[1]. The time-stamp is generated at a packet master function and is carried over a packet network to a packet slave clock. As time is the integral of frequency, the time-stamps can therefore be used to derive frequency.

7.1 Packet-based frequency distribution

The three main components are the packet master clock, the packet slave clock and the packet network. A packet timing signal generated by the packet master clock is transported over the packet network so that the packet slave clock can generate a clock frequency traceable to the input timing

[1] In some cases frequency may be derived from the arrival rate of incoming packets that do not contain a time-stamp, but that rather are generated at precise intervals. As this Recommendation deals with the use of time-based protocols, methods to derive frequency from the arrival rate of packets are outside the scope of this Recommendation.

signal available at the packet master clock. The packet master clock is presented with a timing signal traceable to a PRC. The clock produced at the packet slave clock represents the clock traceable to the PRC plus some degradation (δ) due to the packet network. The general architectural topology is shown in Figure 1. The synchronization flow is from master to slave. In cases where the reference to the master is provided over a synchronization distribution network, additional degradation of the frequency signal may be present at the input to the master and therefore also at the output of the slave.

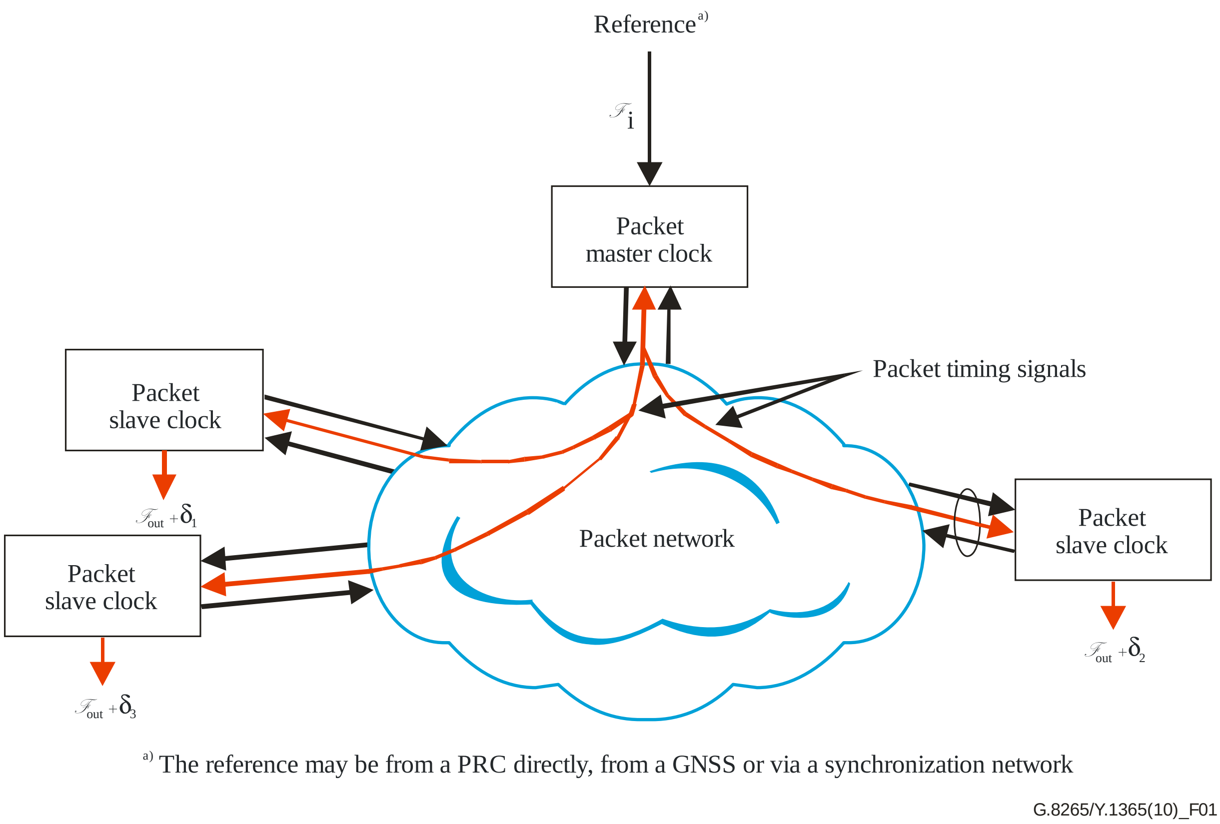

Figure 1 – General packet network timing architecture

7.2 Timing protection

7.2.1 Packet master protection

In traditional synchronization networks, timing availability is enhanced by the use of timing protection whereby the timing to a slave clock (e.g., SEC, or EEC) may be provided over one or more alternative network paths. In the case of the packet-based timing architecture, slave clocks may have visibility to two or more master clocks, as shown in Figure 2.

In contrast to physical layer timing, where the selection of the clock is performed at the slave clock, selection of a secondary master clock may involve some communication and negotiation between the master and the slave, and the secondary master and slave.

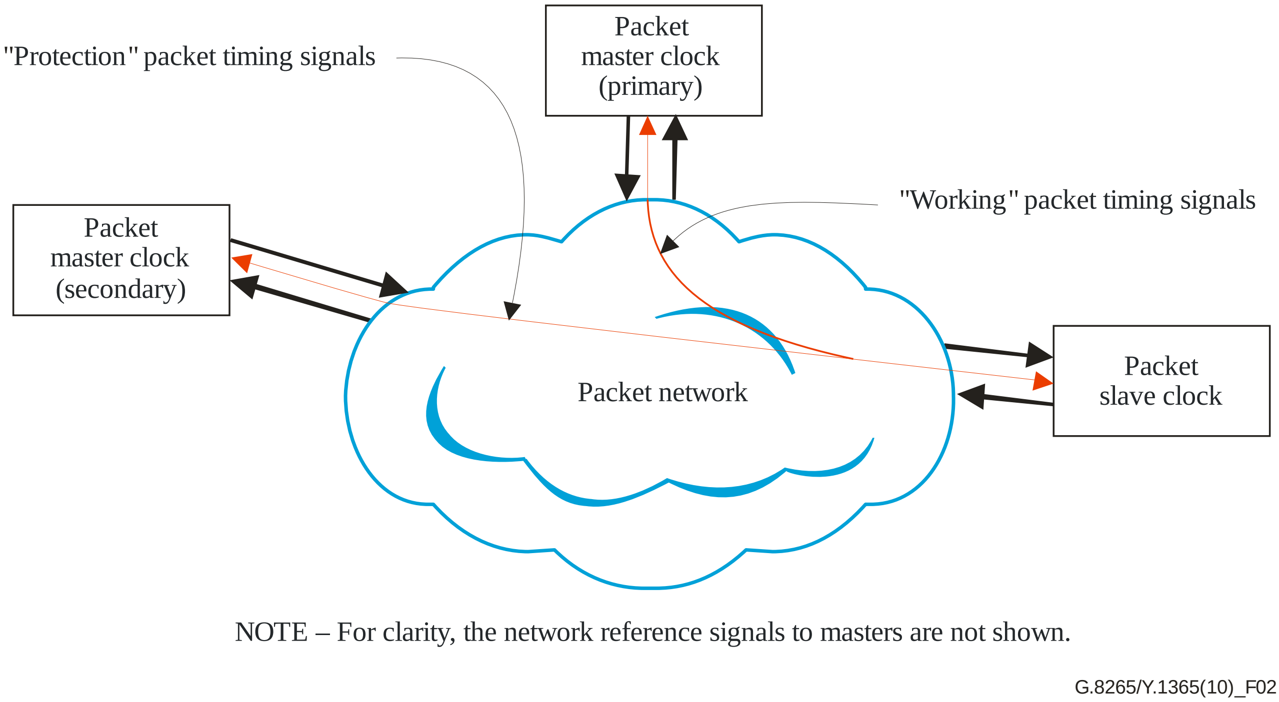

Figure 2 – Packet network timing (frequency) protection

7.2.2 Packet master/slave selection functions

Functions required in order to support packet reference selection are described in the following clauses.

7.2.2.1 Temporary master exclusion – Lock-out function

To protect the downstream architecture, it must be possible in the slaves to exclude temporarily a master from a list of candidate masters (lock-out functionality).

7.2.2.2 Slave wait-to-restore time function

To protect the downstream architecture, a wait-to-restore time must be implemented in the slave. If a master fails or is unreachable, a slave will switch to a backup master. However, upon the recovery of the primary master, the slave will not switch back to the primary master until the wait-to-restore time expires.

7.2.2.3 Slave non-reversion function

To protect the downstream architecture, a slave non-reversion function may be implemented to protect against slaves "flipping" between masters.

This will ensure that if a master fails or is not reachable anymore, a slave will switch to a backup master but will not switch back to the primary master if the non-revertive mode is implemented and activated.

7.2.2.4 Forced traceability of master function

It must be possible to force the QL traceability value at the input of the packet master clock.

Network implementations and scenarios making use of this functionality will need to be defined by the operator on a case by case basis and will depend on the operator's architecture.

This function is illustrated in Figure 3.

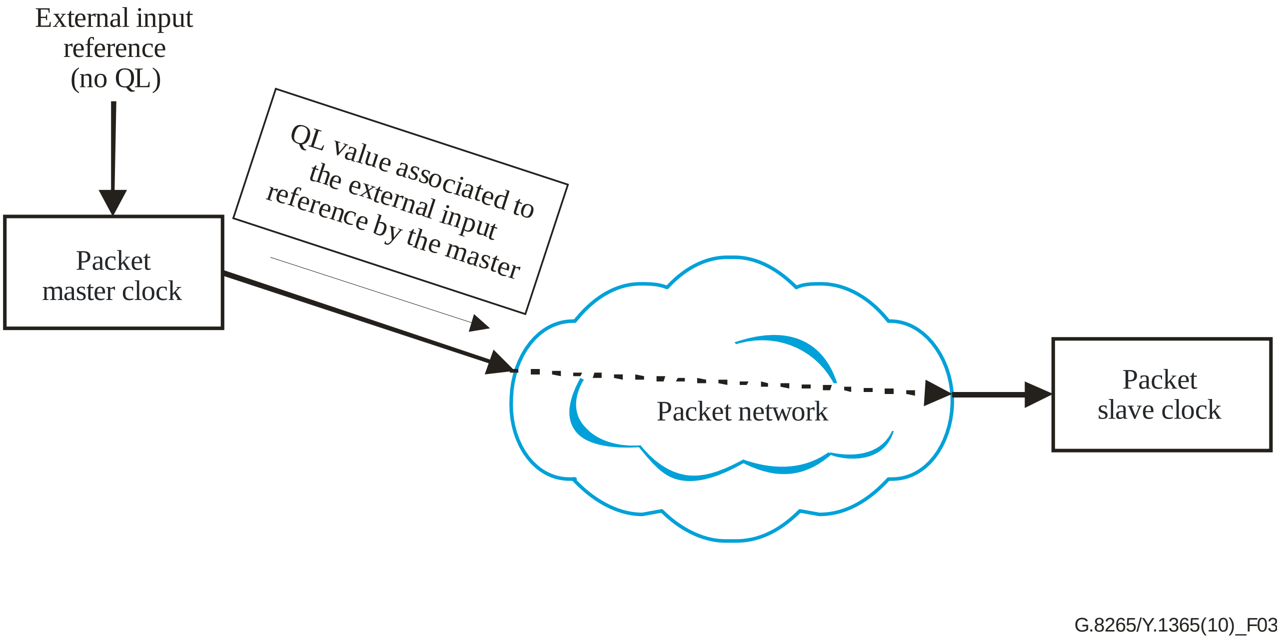

Figure 3 – Example of use case where forcing the QL value at the input of the PTPv2 master is needed

7.2.2.5 Packet slave clock QL hold off function

In the case where sufficient holdover performance exists within the packet slave clock, it must be possible to delay the transition of the QL value at the output of the slaves. This will allow the operator to limit downstream switching of the architecture under certain network implementations when traceability to the packet master is lost.

NOTE – The QL hold off is highly dependent on the quality of the clock implemented in the slave and is for further study.

These network implementations and scenarios will need to be defined by the operator on a case by case basis.

This function is illustrated in Figure 4.

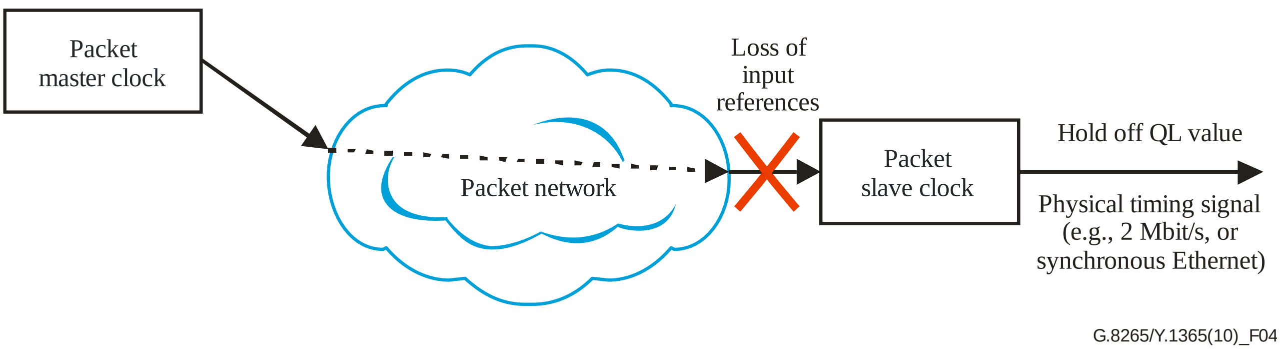

Figure 4 – Example of use case where the QL hold off at the output of the packet slave clock

7.2.2.6 Slave output squelch function

In case the packet slave provides an external output synchronization interface (e.g., 2 MHz), a squelch function must be implemented in order to protect the downstream architecture and certain end applications.

This function is used under certain upstream packet timing signal failure conditions between the packet master and the packet slave.

These network implementations and scenarios will need to be defined by the operator on a case by case basis. For example, one application will be the case of a packet slave external to the end equipment, such as a base station, which may implement better holdover conditions compared to the packet slave. In this case, it is recommended to squelch the signal at the output of the packet slave in packet timing failure conditions, so that the end equipment will switch into holdover rather than synchronizing the end equipment with the holdover of the packet slave.

Architectural implementations using this function are for further study. The function is illustrated in Figure 5.

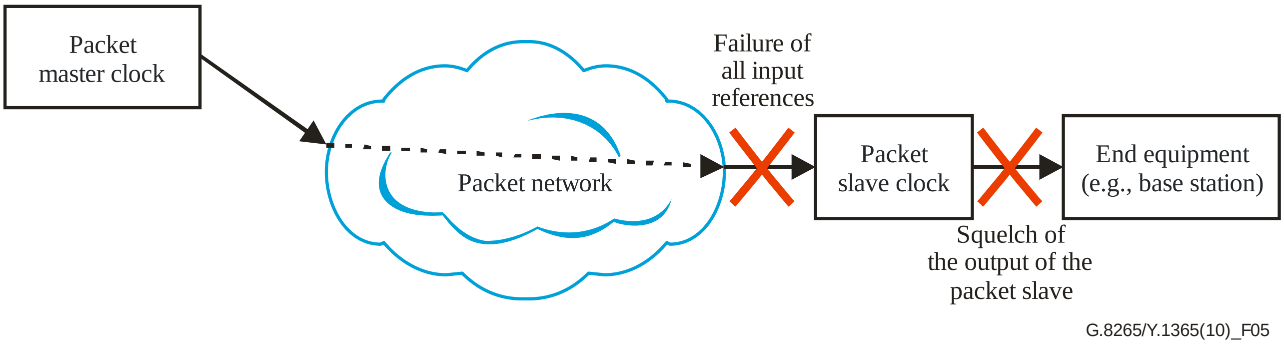

Figure 5 – Squelching at output of packet slave

7.3 Packet network partitioning

Packet networks may be partitioned into a number of different administrative domains. The transport of timing across the packet network must consider the partitioning of networks into different administration domains, as illustrated in Figure 6. This could mean, for example, that packet master clocks may be located in different administrative domains. Operation in this configuration may be limited due to the protocol capabilities and is for further study.

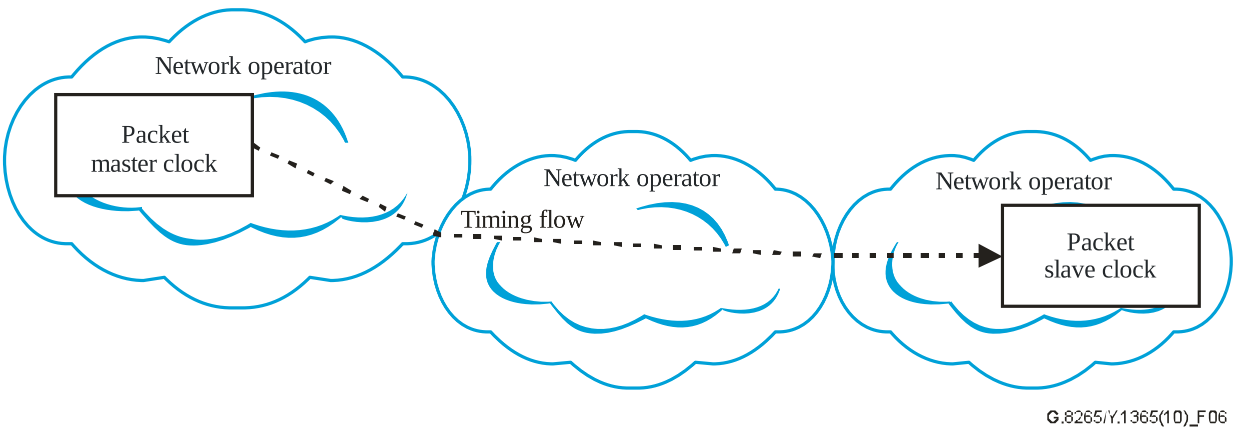

Figure 6 – Packet timing flow over partitioned network

Passing packet-based timing between administrative domains is not currently specified in this version of the Recommendation and is for further study. There are issues surrounding the demarcation of the packet timing flow and the transferred performance between operators.

Due to the operation of packet-based networks and their impact on packet-based timing recovery, especially under stress conditions, derived performance is difficult to characterize. Concerning the end-to-end recovery of timing from the packet timing flow, situations can exist where it is difficult to determine the location of performance problems, especially if the packet timing is passing through multiple administrative domains.

When multiple administrative domains are involved, other methods that are based on physical layer synchronization (for example, synchronous Ethernet over OTN) may be applicable for frequency distribution. The details are outside the scope of this Recommendation. Further information can be found in clause 11 of [ITU-T G.8264].

7.4 Mixed technologies

Packet services may be carried over a packet switching network where the core and access are carried over different technologies. This may impact packet delay variation performance and the ability of the slave clock to derive frequency. For example, within the core, packets containing time-stamps may traverse routers, switches or bridges interconnected by Ethernet links, while the access portion interconnect may be xDSL or PON.

A connection through a network may consist of a concatenation of different technologies. The PDV performance may be different based on these technologies. The aggregate PDV may therefore differ when mixes of different technologies are deployed. A slave clock may need to accommodate the impact of using different technologies.

Details of the PDV contributions of individual transport technologies and the performance of slave clocks are for further study.

8 Packet-based protocols for frequency distribution

8.1 Packet-based protocols

As noted in clause 6, frequency transfer over packet networks is not inherent in the packet layer. In cases where frequency transfer is required, methods such as circuit emulation, which utilize either differential or adaptive clock recovery methods may be employed [ITU-T G.8261].

Protocols for distribution of time exist such as NTP and PTP [IEEE 1588]. Although the protocols are primarily intended for the distribution of time, it is also possible to derive frequency. A general description on the protocols as well as clarifications on the need to define further details when using these protocols for the purpose of frequency distribution is provided below. Note that the performance achievable may also depend on factors outside of the protocol definitions.

8.2 PTP [IEEE 1588] general description

[IEEE 1588] describes the "precision time protocol", commonly referred to as PTP. The PTP protocol enables the accurate time-transfer between two entities (clocks) by the transmission of messages containing accurate timestamps representing an estimate of the time at which the packet is sent. The repeated transmission of messages also allows the derivation of frequency.

The PTP protocol supports unicast and multicast operation. Additionally, the protocol provides the support for two clock modes, a one-step mode and a two-step mode, which involves the transmission of an additional Follow-up message. Additional messages are also defined for other purposes, such as signalling and management.

While the first version of [IEEE 1588] was developed for industrial automation, the second version was extended to be applicable to other applications such as telecom. The protocol may be tailored to specific applications by the creation of "profiles" which specify which subset of functionality may be required, together with any related configuration settings, to satisfy a specific application. ITU-T is concerned with application to telecom environments.

[IEEE 1588] defines several types of clocks: ordinary, boundary and transparent clocks. While the standard defines clocks, these are only high level constructs. The performance achievable by the PTP protocol is based on factors that are outside the scope of [IEEE 1588].

[b-ITU-T G.8265.1] contains a PTP profile applicable to telecom applications using ordinary clocks in an unicast environment. Profiles developed by ITU-T are intended to meet all the high-level requirements specified in this Recommendation.

8.3 NTP – General description

NTPv4 is defined in [IETF RFC 5905], which obsoletes both [b-IETF RFC 1305] (NTP v3), and [b-IETF RFC 4330] (SNTP).

[IETF RFC 5905] defines both a protocol and an algorithm to distribute time synchronization, however the NTP on-wire protocol can also be used to distribute a frequency reference. In this case, however, a specific algorithm to recover frequency has to be developed, and only the packet format and protocol aspects need to be considered. The specific implementation in the client for the purpose of frequency synchronization clock recovery can be considered similar to an implementation using other packet protocols.

According to [IETF RFC 5905], an SNTP client is not required to implement the NTP algorithms specified in [IETF RFC 5905]. In particular, [IETF RFC 5905] notes that primary servers and clients complying with a subset of NTP, called the simple network time protocol (SNTP), do not need to implement the mitigation algorithms described in the relevant sections of [IETF RFC 5905]. The SNTP client can operate with any subset of the NTP on-wire protocol through the simplest approach, using only the transmit timestamp of the server packet and ignoring all other fields.

Among the aspects to consider is that in some applications the required packet rate may need to be higher (lower MINPOLL value) than the limit currently suggested for the time synchronization algorithm specified in [IETF RFC 5905]. In relation to this, [IETF RFC 5905] indicates, with respect to the MINPOLL parameter, that "These are in 8-bit signed integer format in log2 (log base 2) seconds... [and] suggested default limits for minimum and maximum Poll intervals are 6 and 10, respectively".

NOTE – The detailed way of using NTP for the specific application e.g., including the method to support SSM according to the requirements of clause 6, is for further study.

More details on the use of timing packets (such as NTP) for the purpose of frequency transfer are provided in Appendix XII (Basic principles of timing over packet networks) of [ITU-T G.8261].

9 Security aspects

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

It is important to permit the operation with existing, standards-based security techniques to help ensure the integrity of the synchronization. Examples may include encryption and/or authentication techniques, or network techniques for separating traffic, such as VLANs or LSPs. Specifically,

– slaves should be prevented from connecting to rogue masters (this could be either by an authentication process or by using network separation to prevent rogue masters from accessing slaves);

– masters should be prevented from providing service to unauthorized slaves.

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

Security aspects are for further study.

Appendix I

Bibliography

[b-ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (2010), *Timing characteristics of a synchronous Ethernet equipment slave clock*.

[b-ITU-T G.8265.1] Recommendation ITU-T G.8265.1/Y.1365.1 (2010), *Precision time protocol telecom profile for frequency synchronization*.

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

[b-IETF RFC 4330] IETF RFC 4330 (2006), *Simple Network Time Protocol (SNTP) Version 4 for IPv4, IPv6 and OSI*.

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