ITU-T Q13/15 activity and its relation with the leap second

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Calnex solutions
Q13/15

Network synchronization and time distribution performance

Q13 has already studied network synchronization issues related to PDH and SDH from 1988 until 2000, and to OTN in 2001-2004 and 2008-2012 Study Periods. This question has also started studying the network synchronization issues related to packet networks with focus on mobile network needs from 2004 until 2012.

Continuing effort needs to be put into the study of synchronization issues in packet based networks.
Need for synchronization

In the 1970’s digital switches had to be synchronized (syntonized in fact) to prevent slips. PDH links 2.048 and 1544 Mbits could transport timing between switches.

In the 1990’s SDH &SONET networks provided a new synchronization network. In the 1990s, NTP was considered accurate enough for the existing applications.

The OTN (Optical Transport Network) specified at the beginning of the 2000’s was not defined to be a new synchronization network, but simply to be transparent to the existing SDH one.
Need for synchronization

In the 1990’s the emerging mobile networks were specified to operate within a 50 ppb frequency accuracy.

- The reference timing was transported with the data via synchronized 2Mbits signals.

The evolution of telecom networks toward packet networks has generated a new need to transport a reference frequency through packet networks for FDD networks requiring 50ppb accuracy.

- The evolution of mobile networks toward TDD techniques added a new requirement for the transport of time with an accuracy of 1.5 µs.
Q13 milestones

Until 2003 transport of frequency over
- PDH, SDH, OTN

2003-2013 transport of frequency over packet networks via
- CES
- synchronous Ethernet
- IEEE 1588 V2

2011-2013 transport of phase and time over packet networks via IEEE 1588 V2
- work still ongoing
synchronous Ethernet

- based on SDH clocks and network architecture

- totally compatible with SDH
  * SyncE links and SDH links can be chained
  * a synchronization network may have both SDH and SyncE network elements

- But it does not transfer time
  * could be done using packets with SSM
  * but it was preferred to use the new IEEE 1588
SyncE equipment

SyncE NE

Clock recovery → switch → data

Equipment clock

Free running oscillator

Codex equipment

Eth NE

Clock recovery → switch → data

SyncE equipment

Synchronous ethernet equipment
# TDM and SyncE standards

<table>
<thead>
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<th>Category</th>
<th>TDM</th>
<th>SyncE</th>
</tr>
</thead>
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<td>G.810</td>
<td></td>
</tr>
<tr>
<td>Architecture</td>
<td>G.803</td>
<td>G.8261</td>
</tr>
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<td>Performance</td>
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<td>G.8261</td>
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<tr>
<td>Test equipment</td>
<td>O.171/172</td>
<td>O.174</td>
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</tbody>
</table>
Packet networks and PDV

In packet networks switches/routers store packets in buffers as they arrive and transmit them when possible in the outgoing link.

The transfer delay through a switch/router highly depends on the traffic and the design of the switch/router implementation.

This packet delay variation, PDV, degrades the quality of timing.

PDV may reach tens or hundreds of $\mu$s in a packet network, to be compared with 1.5$\mu$s accuracy requested for TDD mobile applications.
IEEE Std 1588™ - 2008

IEEE 1588-2008 defines a Precision Time Protocol designed to synchronize clocks in a distributed system.

It is intended for Telecom networks, and other applications.

It defines several types of clocks, e.g. BCs and TCs, with mechanisms reducing the amount of PDV.

It offers a lot of options; each application must select them in a « profile »
- One way vs two way
- Mapping, IP V4, V6, Eth etc
- Rate and type of messages
- etc
transport of frequency over packet networks using IEEE-1588

Q13 decided to study a first « end to end » profile where:
- the transport of frequency is done via IEEE 1588 messages
- The IEEE 1588 Grand Master delivers the PTP messages
- The slave clock extracts the timing from the PTP messages and delivers the frequency
- Equipment located between the grand Master and the Slave clock are basic switches/routers, unaware of IEEE 1588, providing a solution for existing packet networks
Recommendations for Frequency

Definitions / terminology
- G.8260 (Definition)
- G.8260 AppI (metrics)
- General
- IEEE1588
- SyncE

Basics
- G.8261

Network requirements
- SyncE Jitter-Wander: (Included in G.8261)
- G.8261.1 (NetwkPDV_frequency)

Clock
- G.8262 (SyncE)
- G.8263 (slave clock)

Methods
- G.8264 (SyncE-architecture-SSM)
- G.8265 (architecture-Frequency)

Profiles
- G.8265.1 (PTPprofileFrequency)
- G.8265.m (PTP_Profile frequency m)

Frequency: G.826x

Time/Phase: G.827x
Transport of frequency in packet networks

IEEE 1588 Profile

End to end Profiles Tbd

SDH + SyncE

IEEE 1588 Grand master

G.810 metric, ...

G.8260 metric

G.8260metric G.8261.1

G.8261 G.8261.1 G.8265 G.8265.1

PRC

CES G.8261

Slave G.8263

Mobile application

G.8261 G.8262 G.8264

G.8261 G.8261.1 G.8265 G.8265.1

G.8265 G.8265.x
G.8261.1 defines 2 HRMs (HRM= hypothetical reference model)

Packet node (e.g., Ethernet switch, IP router, MPLS router)

- 10 Gbit/s fibre optical link
- 1 Gbit/s fibre optical link

Microwave link
G.8261.1 defines the performance of the transport for mobile application.

For short observation time it follows the 2 Mbits mask defined for traffic interfaces. For longer observation times it must comply with the requirement of the end user.
G.8265 specifies the network architecture and addresses the protection aspects.

*a* The reference may be from a PRC directly, from a GNSS or via a synchronization network.
G.8265.1

G.8265.1 specifies the profile for frequency distribution without timing support from the network (PTP messages not processed in equipments between master and slave)

Mapping: IP
Mode: one-way or two-way
Unicast mode
Message rates
Protection: definition of an alternate BMCA (Best Master Clock Algorithm)
Extensive simulations were done to validate the specifications done for the transport of frequency using IEEE 1588. A supplement called G.SUPPxx will present the simulation results.
transport of phase and time over packet networks using IEEE-1588

Transport of time implies a two-way mode to take into account the transport delay between the master clock and the slave clock.

IEEE 1588 is based on TAI time but it also provides an information to get UTC, called the « currentUtcOffset »
IEEE 1588 propagation delay

The delay in the propagation of time between two Clocks is calculated with the time stamps of messages in the master and the slave as half of the roundtrip delay

\[ \text{Delay} = \frac{(t2-t1)+(t4-t3)}{2} \]

The asymmetry in the two direction delays is one of the main source of inaccuracy.
Recommendations for F and T

Definitions / terminology

G.8260
(Definition)

G.8260 AppI
(metrics)

Agreed

Consent

Ongoing

Basics

G.8261

Freqeny: G.826x

G.8261.1
(NetwkPDV_frequency)

SyncE Jitter-Wander:
(Included in G.8261)

Time/Phase: G.827x

G.8271

G.8271.1
(NetwkPDV_time/phase)

G.8271.2(profile2)

G.8272
PRTC

73.1 GM

73.2 BC

73.3 TC

73.4

G.8273

G.8275
(architecture-time)

G.8275.1
(PTPProfile1Time/phase)

G.8275.2
(PTPProfile2Time/phase)

Network requirements

G.8260 AppI
(metrics)

Recommendations for F and T

Ongoing

Agreed

Consent

Clock

G.8261

G.8262
(SyncE)

G.8263
(slave clock)

Methods

G.8264
(SyncE-architecture-SSM)

G.8265
(architecture-Frequency)

Profiles

G.8265.1
(PTPProfileFrequency)

G.8265.m
(PTP_Profile frequency m)
Transport of time and phase in packet networks

- **Primary time Standard**
- **SDH + SyncE**
  - G.8261
  - G.8262
  - G.8264
- **Full support Profile**
  - G.8271
  - G.8271.1
  - G.8273.2
  - G.8275
  - G.8267.1
- **Partial Support Profile**
  - G.8271
  - G.8271.2
  - G.8273.x?
  - G.8275
  - G.8275.2
- **Slave**
  - G.8273.x
- **Mobile application**

- **G.8272**

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**Calnex**
G.8271: network model

Note that:
-G.8272 specifies the global specification of PRTC and packet master clock (processing IEEE 1588), although PRTC might also remain a stand alone equipment
-packet slave clock might be colocated with the end application Time clock
G.8271.1 HRMs
Hypothetic reference Models

HRM1 without physical layer frequency support

HRM-2 with physical layer frequency support – congruent scenario
HRM-3 with physical layer frequency support – non congruent scenario
G.8271.1: Noise budget

Based on extensive simulations

BC noise : 50ns
(another BC with lower noise should also be specified)

<table>
<thead>
<tr>
<th>Budget Component</th>
<th>Failure scenario a) (change of PRTC)</th>
<th>Failure scenario b)</th>
<th>Long Holdover periods (e.g. 1 day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRTC ($c_{ref}$)</td>
<td>100 ns</td>
<td>100 ns</td>
<td>100 ns</td>
</tr>
<tr>
<td>Holdover and Rearrangements in the network ($TE_{HO}$)</td>
<td>NA</td>
<td>400 ns</td>
<td>2400 ns</td>
</tr>
<tr>
<td>Random and error due to synchronous Ethernet rearrangements ($dTE'$)</td>
<td>200 ns</td>
<td>200 ns</td>
<td>200 ns</td>
</tr>
<tr>
<td>Node Constant including intrasite ($c_{pp_clock}$) (Note1)</td>
<td>550 ns</td>
<td>550 ns</td>
<td>550 ns</td>
</tr>
<tr>
<td>Link Asymmetries ($c_{link asym}$)</td>
<td>250 ns</td>
<td>100 ns</td>
<td>100 ns</td>
</tr>
<tr>
<td>Rearrangements and short Holdover in the End Application ($TE_{REA}$)</td>
<td>250 ns</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>End application ($TE_{EA}$)</td>
<td>150 ns</td>
<td>150 ns</td>
<td>150 ns</td>
</tr>
<tr>
<td>Total ($TE_0$)</td>
<td>1500 ns</td>
<td>1500 ns</td>
<td>3500 ns (Note3)</td>
</tr>
</tbody>
</table>

Scenario a) change of Grand master
Scenario b) Short interruption of the GNSS signal (e.g. 5 minutes)
This HRM is under definition

The basic of this HRM is to have
- 1588 unaware equipments
- Might have Boundary clocks to filter PDV generated by 1588 unaware Nes
- Numbers of NEs: to be defined
The current architecture deals with Boundary clocks (BC). Transparent clocks will also been considered, after agreement with IEEE 802.1 on the issue of layer violation.
G.8275 Protection

Several positions for PRC, PRTC have been listed to provide protection scenarios, inputs for simulations

Note: T-GM are connected to the PRTC in this architecture
Interest of Q13 in the leap second process

Q13 is responsible for the transport of time to end users, but is not involved in the applications which need time

Q13 does not need time information for operating the transport network

Q13 transports TAI from the PRTC to the end user via IEEE 1588

IEEE 1588 provides an information on the offset between TAI and UTC
## G.8272 PRTC interface

Example of information that could be transferred over the time interface

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>International atomic time, TAI (seconds)</td>
</tr>
<tr>
<td>Leap seconds</td>
<td>Leap seconds (offset between TAI and UTC)</td>
</tr>
<tr>
<td>Leap second addition/subtraction</td>
<td>Provides advance notification of the occurrence of a leap second</td>
</tr>
<tr>
<td>flags</td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>Provides an indication of whether the signal is locked, in holdover, or</td>
</tr>
<tr>
<td></td>
<td>should not be used.</td>
</tr>
</tbody>
</table>
Conclusion

- All processes involved in the transport of time can deliver TAI and UTC, as they have implemented some software to handle leap seconds, i.e.
  - GPS receivers, PRTC
  - IEEE 1588 protocol

- Preservation or removal of leap seconds is not an issue for Q13
  - Current « Q13 network » is compatible with UTC
  - Divergence TAI vs UTC is no problem, for Q13

- But any modification in the leap second process will jeopardize the delivery of UTC at the end application, as it would require modification of equipments and protocols
Where to get the recommendations?

A GIANT LEAP IN 1588V2 PTP MEASUREMENTS

Thank You

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