ITU-T Q13/15, Network synchronization and time distribution performance
Supporting 5G mobile transport and fronthaul

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Geneva, 27 January 2018
Contents

• Q13 Introduction
• Current and new Sync Requirements
• Synchronous Ethernet; Enhanced Synchronous Ethernet
• PTP Telecom Profiles
• Next Steps and Time sync challenges
Q13, Introduction

- Study of synchronization issues in tdm and packet based networks
- Requirements for the related OAM and Management functions
- Requirements from new network architectures and applications (e.g. as related to the IoT, IMT2020 (5G), etc.)
- Robust and reliable network synchronization solutions (e.g. as related to GNSS (Global Navigation Satellite System) backup)
- SDN/NFV implications on the synchronization networks
- Test equipment specification
Q13 Recommendations

Definitions / terminology

Basics

Network requirements

Clocks

Methods

Architecture

Profiles (Protocol)

Related recommendations

Solutions for frequency: G.826x

Solutions for Time/Phase: G.827x

G.8260: Definitions, metrics

G.8271 (Accuracy level 4)

G.8271.1 (lev.4/5/6)

G.8271.2 (lev.4)

G.8273 (Accuracy level 4/5/6)

G.8273.1 (T-GM)

G.8273.2: FTS: T-BC/T-TSC

G.8273.3: FTS: T-TC

G.8273.4: APTS/PTS clocks

G.781

G.781.1

G.703

G.782

G.811 PRC

G.811.1 ePRC

G.812 SSU

G.813 SEC

G.8261

G.8261.1

G.8262 EEC

G.8262.1 eEEC

G.8266 T-GM

G.8264

G.8265

G.8265.1

G.8272 PRTC Class A/B

G.8272.1 ePRTC A/B

SyncE

2018

2019

2018

2019

2018

2019

Legend:

Agreed

ongoing

Planned for YYYY

Synchronization Layer Functions

Interfaces

OAM

Technical Report

Simulation Background

TR GNSS

G.802

G.Suppl.SyncOAM

2018

2018

2018

2019

Deutsche Telekom, Helmut Imlau, 13.10.2017
# Requirements

<table>
<thead>
<tr>
<th>Level of accuracy</th>
<th>Time error requirements (Note 1)</th>
<th>Typical applications (for information)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500 ms</td>
<td>Billing, alarms</td>
</tr>
<tr>
<td>2</td>
<td>100 μs</td>
<td>IP Delay monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asynchronous Dual Connectivity</td>
</tr>
<tr>
<td>3</td>
<td>5 μs</td>
<td>LTE TDD (large cell)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Synchronous Dual Connectivity (for up to 7 km propagation difference between eNodeBs)</td>
</tr>
<tr>
<td>4</td>
<td>1.5 μs</td>
<td>UTRA-TDD, LTE-TDD (small cell)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wimax-TDD (some configurations)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Synchronous Dual Connectivity (for up to 9 km propagation difference between eNodeBs)</td>
</tr>
<tr>
<td>5</td>
<td>1 μs</td>
<td>Wimax-TDD (some configurations)</td>
</tr>
<tr>
<td>6</td>
<td>x ns (Note 3)</td>
<td>Various applications, including Location based services and some LTE-A features (Note 2)</td>
</tr>
</tbody>
</table>

**NOTE 1** – The requirement is expressed in terms of error with respect to a common reference.

**NOTE 2** – The performance requirement is for purposes only, values between 500 ns and 1.5 μs depending on the final specifications of a different level of accuracy.

**NOTE 3** – For the value x, refer to Table 2 below and Table II.2 of Appendix II.

### Level of accuracy

<table>
<thead>
<tr>
<th>Level of accuracy</th>
<th>Maximum Relative Time error requirements (Note 1)</th>
<th>Typical applications (for information)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6A</td>
<td>260ns</td>
<td>Intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation with or without MIMO or TX diversity</td>
</tr>
<tr>
<td>6B</td>
<td>130ns</td>
<td>Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity</td>
</tr>
<tr>
<td>6C</td>
<td>65ns</td>
<td>MIMO or TX diversity transmissions, at each carrier frequency</td>
</tr>
</tbody>
</table>

**NOTE 1** – The maximum relative time error requirements represent the peak-to-peak time difference measured between the elements in the cluster only. See Appendix VII of [ITU-T G.8271.1] for illustration of how requirements are specified in a cluster. In 3GPP terminology this is equivalent to time alignment error (TAE), which is defined as the largest timing difference between any two signals.

- Based on Existing Standards (e.g., 3GPP)
Moving towards 5G; New Fronthaul Demands

- Sync Requirement analysis in cooperation with 3GPP
- New sync requirements for NR (»New Radio«)?
  - TDD currently still satisfied by 3 microseconds (+/- 1.5 microseconds)
  - Ongoing discussion in 3GPP on Carrier Aggregation, CoMP, etc.
- Fronthaul moving towards Ethernet (e.g., legacy requirement of 260 ns, i.e. +/-130 ns)
- Strict requirements to support OTDOA (Observed Time Difference of Arrival)-based positioning (100 ns)
Synchronous Ethernet

- Several applications which require accurate frequency now reached by Ethernet
  - Since the very start of timing over packet network activities, it was proposed to use a synchronous Ethernet physical layer
  - Work done in coordination with IEEE 802.3
  - Compatible with IEEE 802 standards
  - Only in full duplex mode (continuous signal required)
- Based on SDH specification (for interoperability and simplifying the standardization efforts)
  - Ethernet equipment with a synchronous Ethernet Equipment Clock – EEC (G.8262).
  - Synchronous Ethernet interfaces extract the received clock and pass it to the system clock.
  - Synchronization Status Message as per G.8264
  - It does not transport Time (but it has been proposed)
- All nodes must support SyncE: sync chain as per G.803
  - Cannot be transported transparently across network boundaries
- Ongoing work to define an enhanced SyncE (G.8262.1 and revised G.8261)
SyncE: Next Steps

• New Interfaces: jitter generation and tolerance for Synchronous Ethernet interfaces based on 50Gb/s and 100Gb/s PAM4 lanes, as defined in IEEE 802.3bs
• «Enhanced SyncE» for more accurate timing
IEEE1588 and Telecom Profile(s)

- IEEE1588 (PPT, Precision Time Protocol) is the protocol of choice for accurate time synchronization
- Need to develop specific «profile» for Telecom Application,
  - A profile is a subset of required options, prohibited options, and the ranges and defaults of configurable attributes
- Time sync: G.8275.1 and G.8275.2
- Companion Recommendations on performance (clock, network performance, etc.): G.8271.1, G.8273.2/3/4, ..
G.8275.1: Telecom profile for full timing support

- Assumes Boundary Clocks or Transparent Clocks in every node
- 16 packets per seconds
- Delay request/delay response mechanism
- VLAN Tagged frames only between Transparent clocks
- Both the non-forwardable multicast address 01-80-C2-00-00-00-0E and forwardable multicast address 01-1B-19-00-00-00 can be used.
  - The default Ethernet multicast address to be used depends on the operator policy
Time Sync:
Initial focus on +/- 1.5 microsecond

- ITU-T Rec. G.8271 identifies main application areas. E.g., TDD (+/- 1.5 microseconds)
- G.8271.1 provides the related network performance requirements
- **Max abs(TE)** for combined dynamic and constant time error
- **MTIE** («low-frequency») and «peak-to-peak TE amplitude» («high frequency») for dynamic time error

[Diagram showing MTIE over time](attachment:/G.8271.1-1-130601(13)-Amed2(14)_F02.png)

- **TE** (t)
- **Failure in the sync network**
- **TEHO** or **TEREA** budget
- **Holdover-Rearrangement period**

*TEHO* applicable to the network (End Application continues to be locked to the external reference)
*TEREA* applicable to the End Application (End Application handles short rearrangement periods)
Time Sync: Next Steps

- From PRTC (100 ns) to ePRTC (30 ns) and PRTC-B (40 ns)
- From SyncE to eSyncE
- New T-BC/ T-TSC Type C (10 ns?)
- Looking at 5G (with 3GPP) and Fronthaul needs (with IEEE802.1CM)
- End-to-end requirements in terms of «absolute» phase sync (i.e., error vs. a PRTC) and/or «relative» phase sync
Time Sync via PTP: Asymmetry related impairments

• Basic principle: distribute Time sync reference by means of two-way time stamps exchange

• Time Offset= \( t_2 - t_1 - \text{Mean path delay} \)

  Mean path delay = \( \frac{(t_2 - t_1) + (t_4 - t_3)}{2} \)

• As for NTP, also in case of PTP, symmetric paths are required:
  – Basic assumption: \( t_2 - t_1 = t_4 - t_3 \)
  – Any asymmetry will contribute with half of that to the error in the time offset calculation (e.g. 3 \( \mu s \) asymmetry would exceed the target requirement of 1.5 \( \mu s \))
Accurate timestamping and Asymmetries

- Liaison exchanged with IEEE 802.3 on the need for accurate timestamping (impact on timing performance due to Ethernet PHY)
- E.g., FEC may have to be implemented and it could be a source of impairments during the PTP timestamping process (e.g., codeword insertion)
  - Forward delay (df) and reverse Delay (dr) must be symmetric (within x ns tolerance)

Figure 108-1 from IEEE Std 802.3by™-2016, Amendment to IEEE Std 802.3™-2015, (Copyright © 2016 IEEE. All rights reserved)
Summary

• Time sync is a key topic in the area of 5G mobile transport and fronthaul
• Requirements being defined; working in cooperation with 3GPP
• Cooperation with IEEE 802.1 concerning Fronthaul solutions (IEEE 802.1CM)
• Among Key aspects and challenges to address
  – Control of asymmetries in the network
  – Accurate timestamping
  – New more accurate clock types