Synchronization Standards

Silvana Rodrigues (silvana.rodrigues@idt.com)
Agenda

- Synchronization Standards Bodies
- North America synchronization hierarchy
- Stratum levels
- ITU-T synchronization hierarchy
- Clock Types
- IEEE 1588
Synchronization Standards Bodies

- ITU-T, Study Group 15, question 13
  - Frequency, time and phase profiles for IEEE 1588
  - Network and equipment synchronization requirements
- IEEE
  - IEEE 1588
  - IEEE 802.1AS, IEEE 802.1ASbt
  - C37.238 (Power profile)
- ATIS COAST-SYNC
- IETF
  - TICTOC
- There are other SDOs that define synchronization aspects for their specific needs, e.g.:
  - 3GPP defines synchronization requirements with particular focus on the radio interface
  - MEF defines synchronization requirements for Circuit Emulation and for Mobile Backhaul Implementation Agreement
Network Elements clocks
• Defined in ANSI T1.101, Telcordia GR-1244-CORE
  Used in PBXs, Access router, etc…

Network Elements clocks
• Defined in ANSI T1.101, Telcordia GR-1244-CORE, GR-253-CORE (SONET)
  Used in Routers, ADMs, MSPPs etc.

High quality clocks
• Defined in ANSI T1.101, Telcordia GR-1244-CORE
  Often used in BITS

Highest quality clocks: Frequency accuracy $< 10^{-11}$
• Defined in ANSI T1.101

North America Synchronization Hierarchy

Primary Reference Source (PRS)

Central Office Clock

Stratum 1 (ST1)

Stratum 2 (ST2)

Stratum 3E (ST3E)

Stratum 3 (ST3)

Stratum 3 (ST3)

Stratum 4 (ST4)

Stratum 4 (ST4)

Stratum 4 (ST4)

Stratum 4 (ST4)

BITS – Building Integrated Timing Supply
Stratum Levels

• The stratum levels are associated with the clock performance parameters
  - Free-run accuracy
  - Holdover
  - Output phase transients
  - Pull-in and Hold-in
  - Filtering (PLL Bandwidth)

• The performance parameters for the various levels have been established to assure that synchronization can be transmitted through the network from the most accurate clocks (ST1), through intermediate clocks (ST2, ST3), to the least accurate clocks (ST4)

• The use of payload pointers in SONET necessitates the use of different filtering and wander generation criteria for stratum clocks deployed in NEs that support SONET interfaces
  - The reason for defining clocks in GR-253-CORE

• GR-1244 states “Stratum 3E requirements on filtering of wander and holdover are significantly tighter than the stratum 3 requirements. GR-436-CORE recommends that stratum 3E clocks be the minimum clocks used in BITS applications. In addition, it is recommended that stratum 3E or higher quality clocks not be used in any NE other than a BITS (e.g., it is recommended that transport NEs use stratum 3 or lower quality clocks).
GR-1244-CORE vs. GR-253-CORE

• GR-1244-CORE provides synchronization related criteria from the equipment point of view
  - It describes clocks that may be stand-alone synchronization sources [e.g., Primary Reference Sources (PRSs)], embedded in Network Elements (NEs) whose specific function is to distribute synchronization from a source to other NEs (e.g.; digital switches, Digital Cross-connect Systems (DCSs) or Add-Drop Multiplexers (ADMs)).

• GR-253-CORE contains the Synchronous OpticalNetwork (SONET) specifications
  - GR-253-CORE defines all the aspects of a SONET equipment including clocks to be used in the SONET equipments
  - If the clock requirements are the same as GR-1244-CORE then it refers back to GR-1244-CORE
  - If the clock requirements need to be different from GR-1244-CORE then it is specified in GR-253-CORE
North American Published Standards

- GR-253-CORE - Telcordia Technologies Generic Requirements - Issue 5, October 2009
- GR-1244-CORE - Telcordia Technologies Generic Requirements - Issue 4, October 2009
- ATIS-0900101.2006 - T1.101 - Synchronization Interface Standard
ITU-T Clock Hierarchy (G.803)

Highest quality clocks: Frequency accuracy < $10^{-11}$
- Defined in ITU-T recommendation G.811

Equipment slave clocks
- Defined in ITU-T recommendation G.813
Used in Routers, ADMs, MSPPs etc.

SSU - High quality clocks
- Defined in ITU-T recommendation G.812

SDH Synchronization chain is defined in ITU-T Recommendation G.803
- Consists of 1 PRC followed by 20 SECs, followed by SSU
- The maximum number of SSUs is 10
- Maximum number of clocks is 60

PRC – Primary Reference Clock
SSU - Synchronization Supply Unit
SEC - SDH Equipment Clock
TUPP – Tributary Payload Processor
# Clock Types

<table>
<thead>
<tr>
<th>North America Clock</th>
<th>ST1 (PRS)</th>
<th>ST2</th>
<th>Not Defined</th>
<th>TNC</th>
<th>ST3E</th>
<th>Not Defined</th>
<th>ST3</th>
<th>Not Defined</th>
<th>SMC</th>
<th>ST4E</th>
<th>ST4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITU-T Clock</td>
<td>PRC (G.811)</td>
<td>Type II (G.812)</td>
<td>Type I (G.812)</td>
<td>Type V (G.812)</td>
<td>Type III (G.812)</td>
<td>Type VI (G.812)</td>
<td>Type IV (G.812)</td>
<td>EEC-option 2 (G.8262)</td>
<td>EEC-option 1 (G.8262)</td>
<td>Option 1 (G.813)</td>
<td>Option 2 (G.813)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±1x10⁻¹¹</td>
<td>±1.6x10⁻⁸</td>
<td>Not defined</td>
<td>±1x10⁻⁷</td>
<td>Not defined</td>
<td>±4.6x10⁻⁶</td>
<td>Not defined</td>
<td>±4.6x10⁻⁶</td>
<td>±4.6x10⁻⁶</td>
<td>±20x10⁻⁶</td>
<td>±32x10⁻⁶</td>
</tr>
<tr>
<td>Holdover</td>
<td>Not defined</td>
<td>±1x10⁻¹⁰</td>
<td>2.7x10⁻⁹</td>
<td>±1.5x10⁻⁹</td>
<td>±1.2x10⁻⁸</td>
<td>3x10⁻⁸</td>
<td>3.7x10⁻⁷</td>
<td>2x10⁻⁶</td>
<td>4.6x10⁻⁶</td>
<td>Not defined</td>
<td>Not defined</td>
</tr>
<tr>
<td>Pull-in</td>
<td>Not defined</td>
<td>±1.6x10⁻⁸</td>
<td>±1x10⁻⁸</td>
<td>±1x10⁻⁷</td>
<td>Not defined</td>
<td>±4.6x10⁻⁶</td>
<td>Not defined</td>
<td>±4.6x10⁻⁶</td>
<td>±4.6x10⁻⁶</td>
<td>±20x10⁻⁶</td>
<td>±32x10⁻⁶</td>
</tr>
<tr>
<td>BW</td>
<td>Not defined</td>
<td>0.001Hz</td>
<td>0.003Hz</td>
<td>0.1 Hz</td>
<td>0.001 Hz</td>
<td>0.1 Hz</td>
<td>3 Hz</td>
<td>0.1 Hz (SONET)</td>
<td>1 – 10 Hz</td>
<td>0.1 Hz</td>
<td>Not defined</td>
</tr>
<tr>
<td>Rearrange MTIE</td>
<td>Not defined</td>
<td>≤ 150 ns</td>
<td>≤ 240n</td>
<td>≤ 1μs</td>
<td>≤ 150 ns</td>
<td>≤ 1μs</td>
<td>≤ 1μs</td>
<td>1 μs</td>
<td>1 μs</td>
<td>≤ 1μs</td>
<td>≤ 1μs</td>
</tr>
</tbody>
</table>

ST = Stratum  
SMC = SONET Minimum Clock  
BW = Bandwidth  
MTIE = Maximum Time Interval Error  
OT = Observation Time
ITU-T Published Recommendations (PDH/SDH)

All ITU-T Published Recommendations can be downloaded from:
http://www.itu.int/rec/T-REC-G/e

• ITU T Recommendation G.810, Definitions and terminology for synchronization networks.
• ITU T Recommendation G.811, Timing characteristics of primary reference clocks.
• ITU T Recommendation G.812, Timing requirements of slave clocks suitable for use as node clocks in synchronization networks.
• ITU T Recommendation G.813, Timing characteristics of SDH equipment slave clocks (SEC).
• ITU-T Recommendation G.823, The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy
• ITU-T Recommendation G.824, The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy
• Recommendation ITU-T G.825, The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)
ITU-T Published Recommendations (Packet Sync - Frequency)

All ITU-T Published Recommendations can be downloaded from:
http://www.itu.int/rec/T-REC-G/e

• ITU T Recommendation G.8262, Timing characteristics of Synchronous Ethernet Equipment slave clock (EEC).
• ITU T Recommendation G.8264, Distribution of timing through packet networks
• Recommendation ITU-T G.8261.1, Packet Delay Variation Network Limits applicable to Packet Based Methods (Frequency Synchronization).
• Recommendation ITU-T G.8263, Timing Characteristics of Packet based Equipment Clocks (PEC) and Packet based Service Clocks (PSC)
• ITU-T Recommendation G.8265), Architecture and requirements for packet based frequency delivery
• ITU-T Recommendation G.8265.1, Precision time protocol telecom profile for frequency sync
• ITU-T Recommendation G.8260, Definitions and terminology for synchronization in packet networks
ITU-T Consented Recommendations (Packet Sync – Phase/Time)

All ITU-T Published Recommendations can be downloaded from:

http://www.itu.int/rec/T-REC-G/e

- ITU T Recommendation G.8271, Time and phase synchronization aspects of packet networks
- ITU T Recommendation G.8272, Timing characteristics of Primary reference time clock
- ITU T Recommendation G.8271.1, Network limits
- ITU T Recommendation G.8272, Primary Reference Timing Clock (PRTC) specification
- ITU T Recommendation G.8273, Clock General Requirements
- ITU T Recommendation G.8273.2, Telecom Boundary Clock specification
- ITU T Recommendation G.8275, Architecture for time transport
- ITU T Recommendation G.8275.1, IEEE-1588 profile for time with full support from the network
ITU-T Rec. (Packet Sync – Phase/Time) – work in progress

- ITU T Recommendation G.8273.1, Telecom Grand Master specification
- ITU T Recommendation G.8273.3, Telecom Transparent Clock specification
- ITU T Recommendation G.8273.4, Assisted Partial Timing Support Slave Clocks (APTSC)
- ITU T Recommendation G.8275.2, IEEE-1588 profile for time with partial support from the network
- ITU T G.Sup, Supplement to capture simulation model and results
IEEE 1588

• IEEE Std 1588™-2002 (version 1) was published November 8, 2002
  - Defines a Precision Time Protocol (PTP), therefore is also referenced as PTP
  - IEEE 1588 synchronizes real-time clocks in the nodes of a distributed networked system.

• IEEE Std 1588™-2008 (version 2) was approved March 27, 2008 and published July 24, 2008
  - It is available for purchase from the IEEE web site
    • http://www.ieee.org/web/standards/home/index.html

• Applications
  - Industrial Automation, Test and Measurement, Military, Power generation and distribution, Consumer electronics, and Telecommunications
IEEE 1588 Revision

• Working Group to revise IEEE 1588 was formed
• Project Authorization Request (PAR) was approved in June 2013
  - Correct known technical and editorial errors
  - Precision and accuracy improvements
  - SNMP-compliant MIB
  - Security
  - Clarification of layering, interfaces, and protocol of the standard
  - **Backwards compatibility with version 2 is a must**

• Officers
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THANK YOU!