Synchronization Standards

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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

North America Synchronization Hierarchy

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

High quality clocks
- Defined in ANSI T1.101, Telcordia GR-1244-CORE

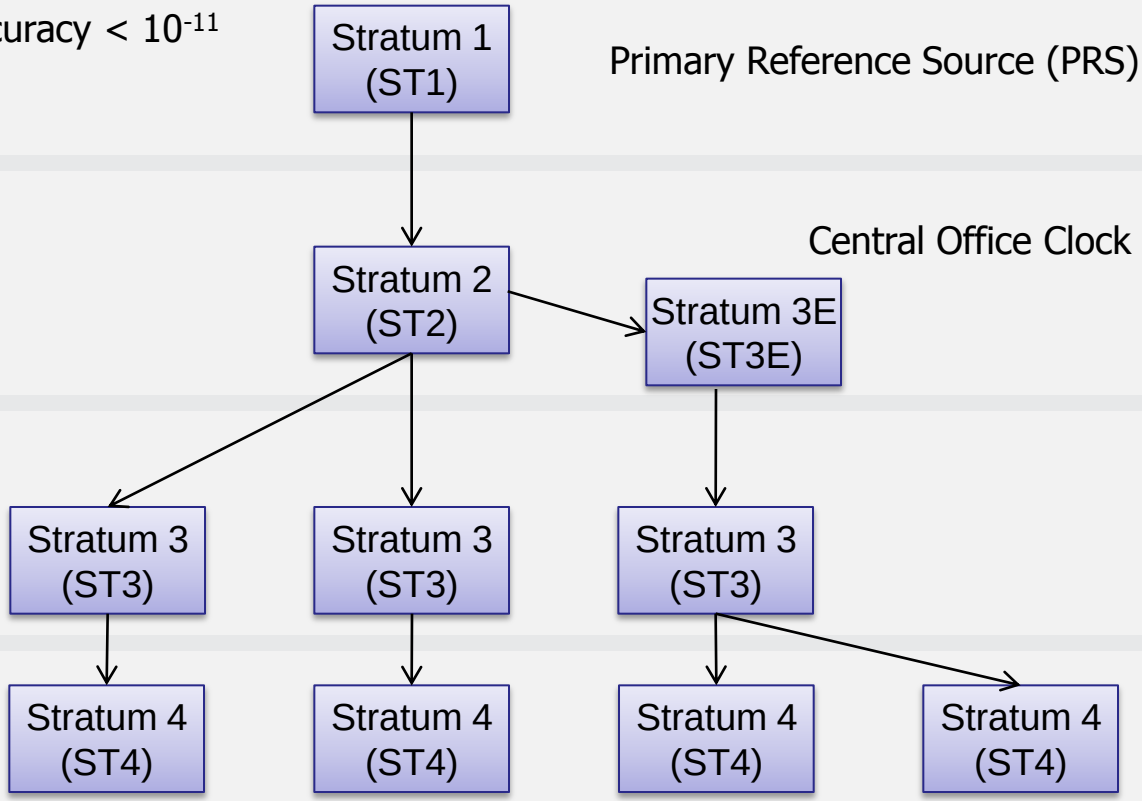
Often used in BITS

Network Elements clocks
- Defined in ANSI T1.101, Telcordia GR-1244-CORE, GR-253-CORE (SONET)

Used in Routers, ADMs, MSPPs etc.

Network Elements clocks
- Defined in ANSI T1.101, Telcordia GR-1244-CORE

Used in PBXs, Access router, etc…



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)

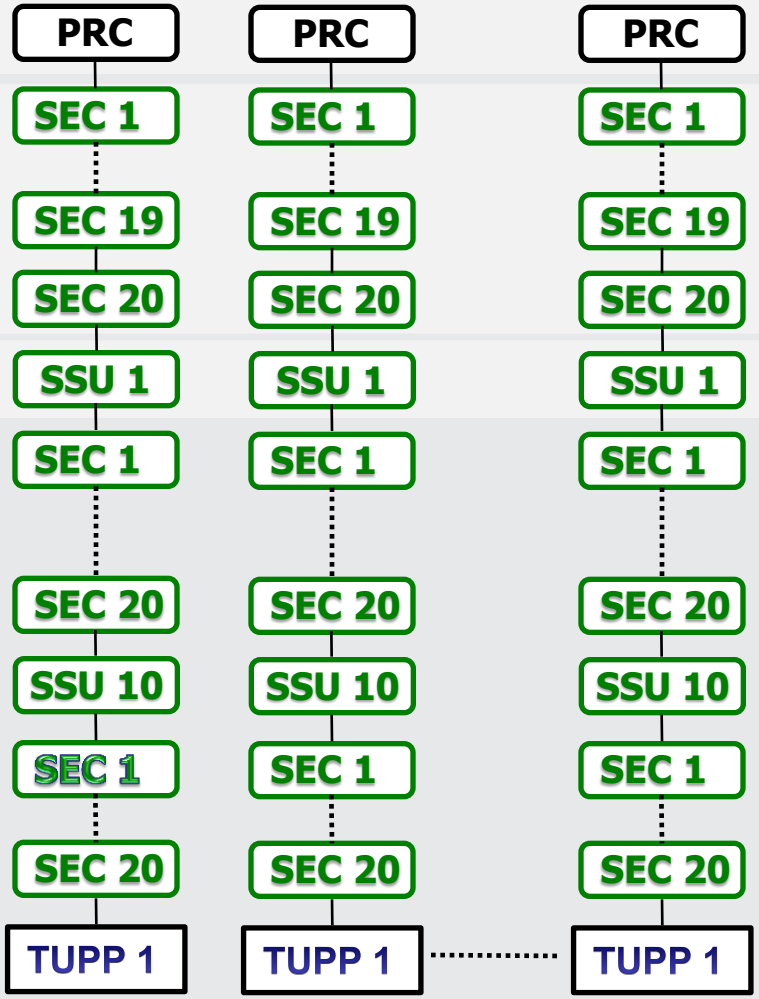
Highest quality clocks : Frequency accuracy < 10^{-11}
- Defined in ITU-T recommendation G.811

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

North America Clock	ST1 (PRS)	ST2	Not Defined	TNC	ST3E	Not Defined	ST3	Not Defined	SMC	ST4E	ST4
ITU-T Clock	**PRC (G.811)**	**Type II (G.812)**	**Type I (G.812)**	**Type V (G.812)**	**Type III (G.812)**	**Type VI (G.812)**	**Type IV (G.812)** **EEC-option 2 (G.8262)**	**Option 1 (G.813)** **EEC-option 1 (G.8262)**	**Option 2 (G.813)**	**Not Defined**	**Not Defined**
Accuracy	$\pm 1 \times 10^{-11}$	$\pm 1.6 \times 10^{-8}$	Not defined	$\pm 1 \times 10^{-7}$ Not defined for ITU	$\pm 4.6 \times 10^{-6}$	Not defined	$\pm 4.6 \times 10^{-6}$	$\pm 4.6 \times 10^{-6}$	$\pm 20 \times 10^{-6}$	$\pm 32 \times 10^{-6}$	$\pm 32 \times 10^{-6}$
Holdover	Not defined	$\pm 1 \times 10^{-10}$	2.7×10^{-9}	$\pm 1.5 \times 10^{-9}$	$\pm 1.2 \times 10^{-8}$	3×10^{-8}	3.7×10^{-7}	2×10^{-6}	4.6×10^{-6}	Not defined	Not defined
Pull-in	Not defined	$\pm 1.6 \times 10^{-8}$	$\pm 1 \times 10^{-8}$	$\pm 1 \times 10^{-7}$ Not defined for ITU	$\pm 4.6 \times 10^{-6}$	Not defined	$\pm 4.6 \times 10^{-6}$	$\pm 4.6 \times 10^{-6}$	$\pm 20 \times 10^{-6}$	$\pm 32 \times 10^{-6}$	$\pm 32 \times 10^{-6}$
BW	Not defined	0.001Hz	0.003Hz	0.1 Hz	0.001 Hz	0.1 Hz	3 Hz 0.1 Hz (SONET)	1 – 10 Hz	0.1 Hz	Not defined	Not defined
Rearrangement MTIE	Not defined	≤ 150 ns OT=5000 (ST2) OT=280 (ITU)	≤ 240n OT=100000s	≤ 1μ OT=64s (TNC) OT=10000s (ITU)	≤ 150 ns OT=64s (ST3E) OT=280s (ITU)	≤ 1μs OT=280s	≤ 1μσ OT=64s (ST3) OT=280s (G.812) OT=10S (G.8262)	≤ 1μs OT=15s	≤ 1μs OT=280s (SMC) OT=10s (ITU)	≤ 1μs OT=64s	Not defined

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.803, Architecture of transport networks based on the synchronous digital hierarchy (SDH).
- 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.8261, Timing and synchronization aspects in packet networks.
- 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
  - Kang Lee (NIST), Sponsor, Project Manager
  - John Eidson, (Calnex Solutions): Co-Chair
  - Doug Arnold (Meinberg): Co-Chair
  - Hans Weibel (ZHAW), Vice-Chair
  - Silvana Rodrigues (IDT): Secretary
  - John Mackay (Progeny Systems): Editor

IEEE

- IEEE Std 1588™-2008, Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.

THANK YOU!

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