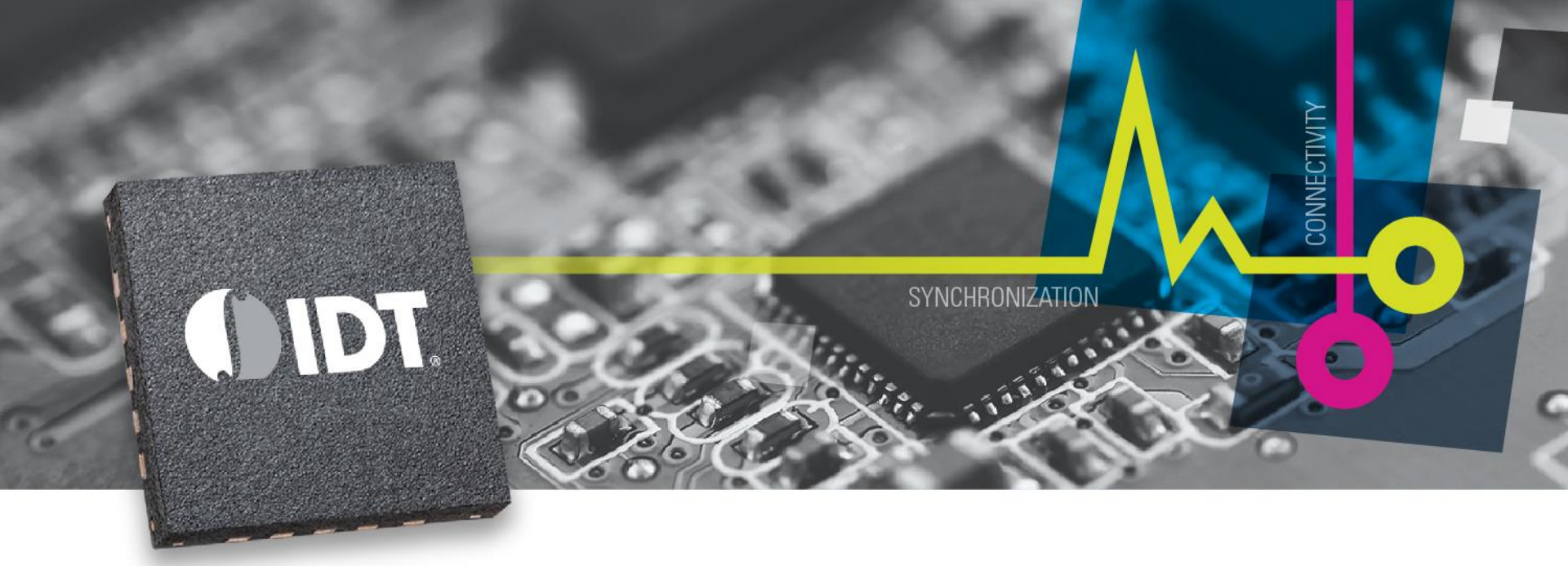


Synchronization Standards

Silvana Rodrigues – IDT (silvana.rodrigues@idt.com)

WSTS – San Jose, April 3 - 6, 2017

Agenda

- Standard Bodies
- SyncE/1588 Standards
- ITU-T Frequency Profile
- ITU-T Time/phase Profiles
- IEEE 1588
- SONET/PDH Standards
- Summary

Synchronization Standards Bodies

- ITU-T (International Telecommunication Union – Telecom Sector), Study Group 15, question 13 Network synchronization and time distribution performance
  - Frequency, time and phase profiles for IEEE 1588
  - Network and equipment synchronization requirements
  - Test and measurement instrumentation

- IEEE (Institute of Electrical and Electronics Engineers)
  - IEEE 1588
  - C37.238 (Power profile)
  - Time-Sensitive Networking Task Group
    - IEEE 802.1AS, IEEE 802.1ASbt
    - IEEE 802.1CM: Wireless Fronthaul

- ATIS (Alliance for Telecommunications Industry Solutions) COAST-SYNC (Copper/Optical Access, Synchronization and Transport)

- IETF (Internet Engineering Task Force)
  - TICTOC (Timing over IP Connection and Transfer of Clock)

- 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. Also defining functions and sync performance at relevant network interfaces

ITU-T 1588 Profiles

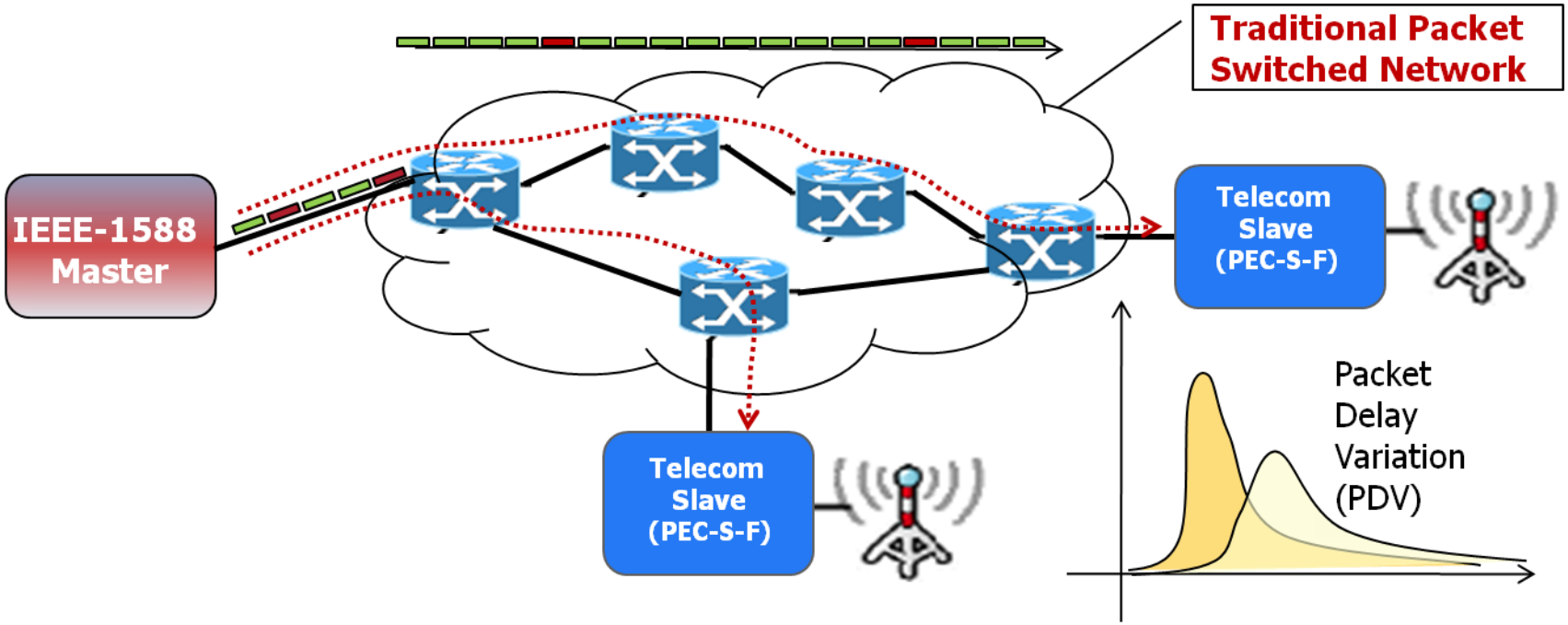
IEEE-1588 Profiles

- IEEE-1588 defines profile as “The set of allowed Precision Time Protocol (PTP) features applicable to a device”
- “The purpose of a PTP profile is to allow organizations to specify specific selections of attribute values and optional features of PTP that, when using the same transport protocol, inter-work and achieve a performance that meets the requirements of a particular application.”
- A PTP profile should define
  - Best master clock algorithm options
  - Configuration management options
  - Path delay mechanisms (peer delay or delay request-response)
  - The range and default values of all PTP configurable attributes and data set members
  - The transport mechanisms required, permitted, or prohibited
  - The node types required, permitted, or prohibited
  - The options required, permitted, or prohibited

* IEEE Std 1588-2008 IEEE Standard for a Precision Clock Synchronization Protocol, copyright 2008 IEEE. All right reserved.

ITU-T Frequency profile

ITU-T G.8265.1 Frequency Profile
IEEE-1588 without support from Network



- Performance is dependent of the network
  - The clock recovery algorithm is adaptive in nature, therefore the performance is impacted by packet delay variation in the network
- The quality of the clock delivered to the application depends on several factors
  - The quality of the oscillator at the slave, the packet delay variation of the network, the number of timing packets per second
- ITU-T consented several Recommendations for IEEE-1588 for Frequency Synchronization targeting wireless backhaul applications
  - G.8265 (Architecture and requirements for packet-based frequency delivery), G.8265.1 (Precision time protocol telecom profile for frequency synchronization), G.8263 (Timing Characteristics of Packet based Equipment Clocks (PEC)), G.8261.1 (Packet Delay Variation Network Limits applicable to Packet Based Methods), and G.8260 (definition of PDV metrics)

G.8265.1 - PTP Options and Configurable Attributes

- One-way versus two-way mode
  - Both one-way and two-way modes are supported in the Frequency Profile
- Unicast versus Multicast mode
  - Only Unicast mode is allowed in the Frequency Profile
  - Unicast Message negotiation is used
- One-step versus two-step clock mode
  - Both one-step and two-step clocks are supported in the Frequency Profile
- PTP mapping
  - IEEE1588-2008 annex D - Transport of PTP over User Datagram Protocol over Internet Protocol Version 4 is supported in the Frequency Profile
  - IEEE1588-2008 annex E - Transport of PTP over User Datagram Protocol over Internet Protocol Version 6 is supported in the Frequency Profile
- PTP Message rates
  - Sync /Follow-up – min rate: 1 packet every 16 seconds, max rate: 128 packets per second
  - Delay_Request/Delay_Response – 1 packet every 16 seconds, max rate: 128 packets per second
  - Announce – min rate: 1 packet every 16 seconds, max rate: 8 packets per second, default: 1 packet every 2 seconds
  - Signaling messages – no rate is specified

G.8265.1 - Alternate BMCA

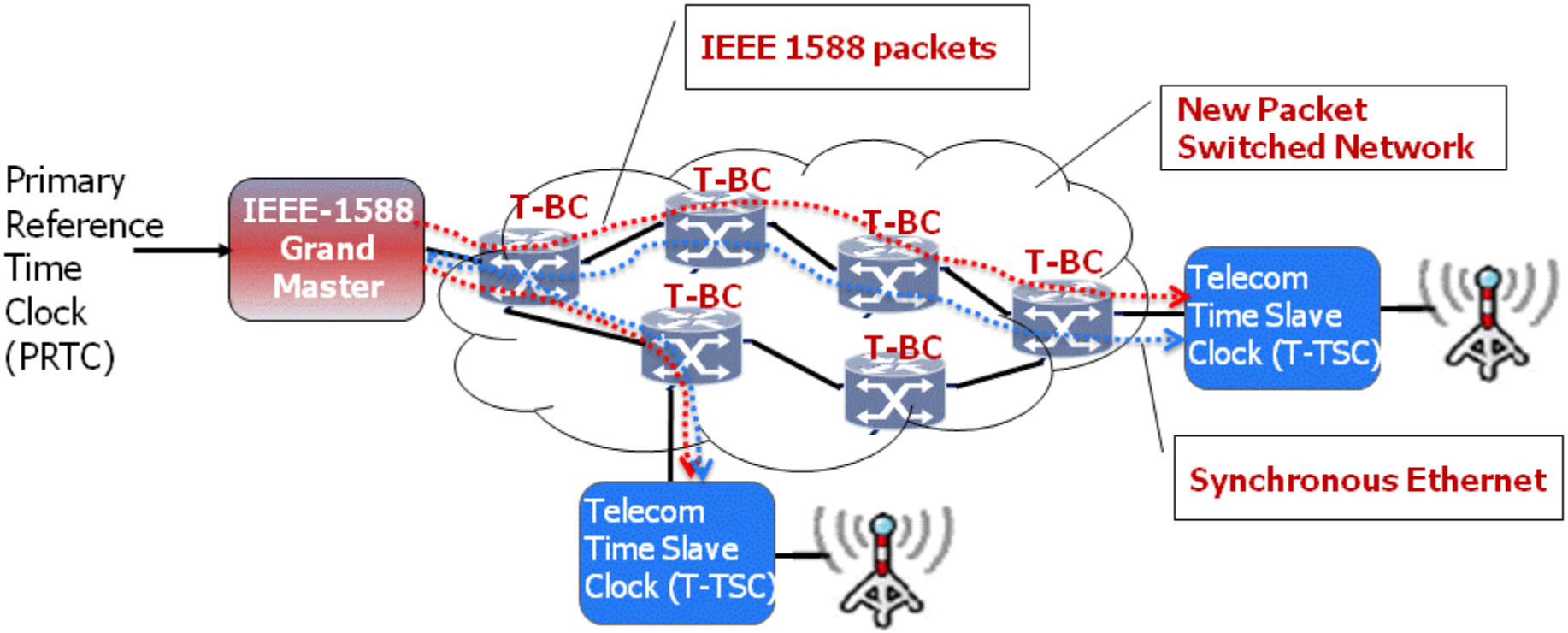
- The alternate BMCA in G.8265.1 is static, each master is isolated by a separated PTP domain that is done through the unicast communication
  - Grandmasters do not exchange Announce messages.
  - Masters are always active
  - Slaves are always slave-only clocks

- The Master selection process is based on the Quality Level (QL)-enabled mode per ITU-T Recommendation G.781
  - Quality Level (QL)
    - The Clock Class attribute in the Announce messages in PTP is used to carry the SSM QL value
    - Master with the highest Quality Level that is not in a failure condition will be selected
    - In case of Masters with similar QL, the Master with the highest Priority is selected.
  - Priority
    - Each master has a priority value that is locally maintained in the Telecom slave.
  - Packet Timing Signal Fail (PTSF)
    - PTSF-lossSync, PTSF-lossAnnounce, PTSF-unusable

- G.8265.1 introduces the concept of a Telecom Slave
  - Consists of one or multiple PTP slave-only ordinary clock instances

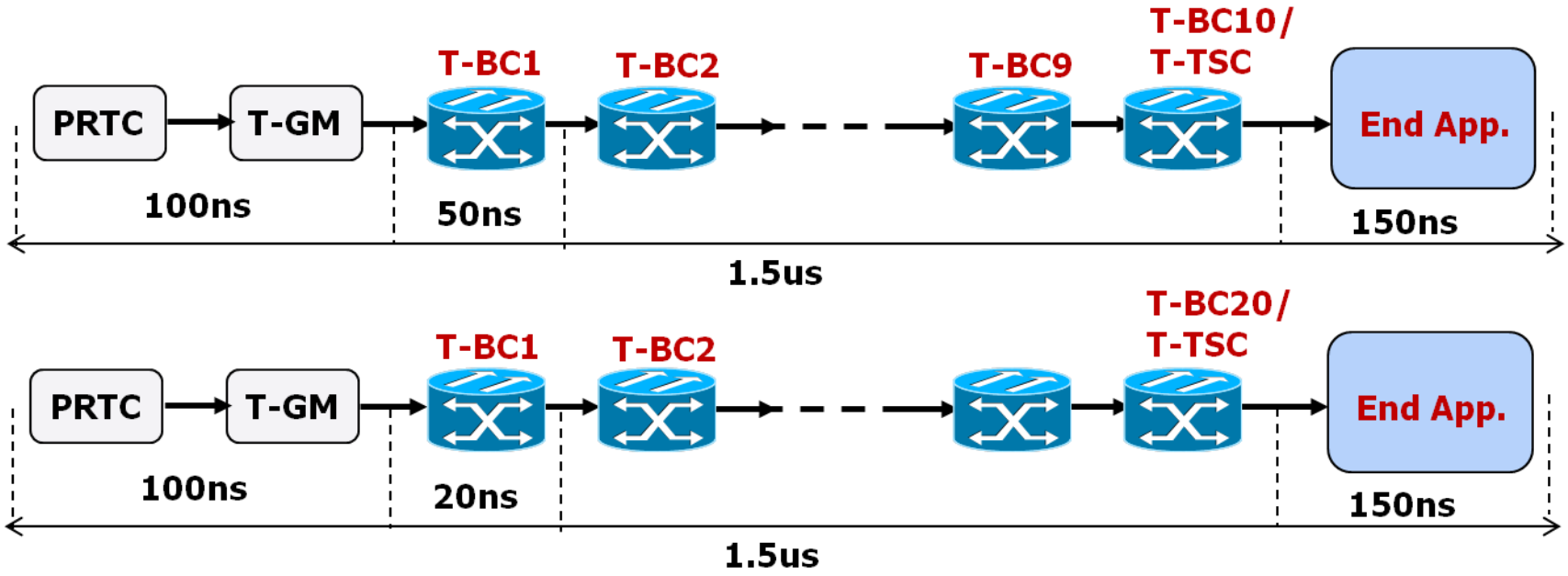
ITU-T Time/Phase profile G.8275.1

G.8275.1- ITU-T Time/Phase Profile
IEEE-1588 with full support from Network



- Telecom Boundary Clocks (T-BCs) and Telecom Transparent Clocks (T-TCs) can be used to overcome the performance issue
- Synchronous Ethernet is used in conjunction with BC for the first version of the profile
- ITU-T have consented several recommendations (G.827x) to address time and phase applications

G.8271.1 Architecture



- G.8273.2 defines the T-BC and T-TSC specifications
- The network limit of 1.5us also accounts for other sources of noise (e.g. holdover, link asymmetries, syncE rearrangements)
- Two classes of Telecom Boundary Clock (T-BC) and Telecom Time Slave Clock (T-TSC)

T-BC Constant TE Classes	Maximum Constant Time Error (ns)
A	50
B	20

G.8273.2/Table 1 – T-BC Constant Time Error Classes

PRTC = Primary Reference Time Clocks
T-GM = Telecom Grand Master

G.8275.1 PTP Options and Configurable Attributes

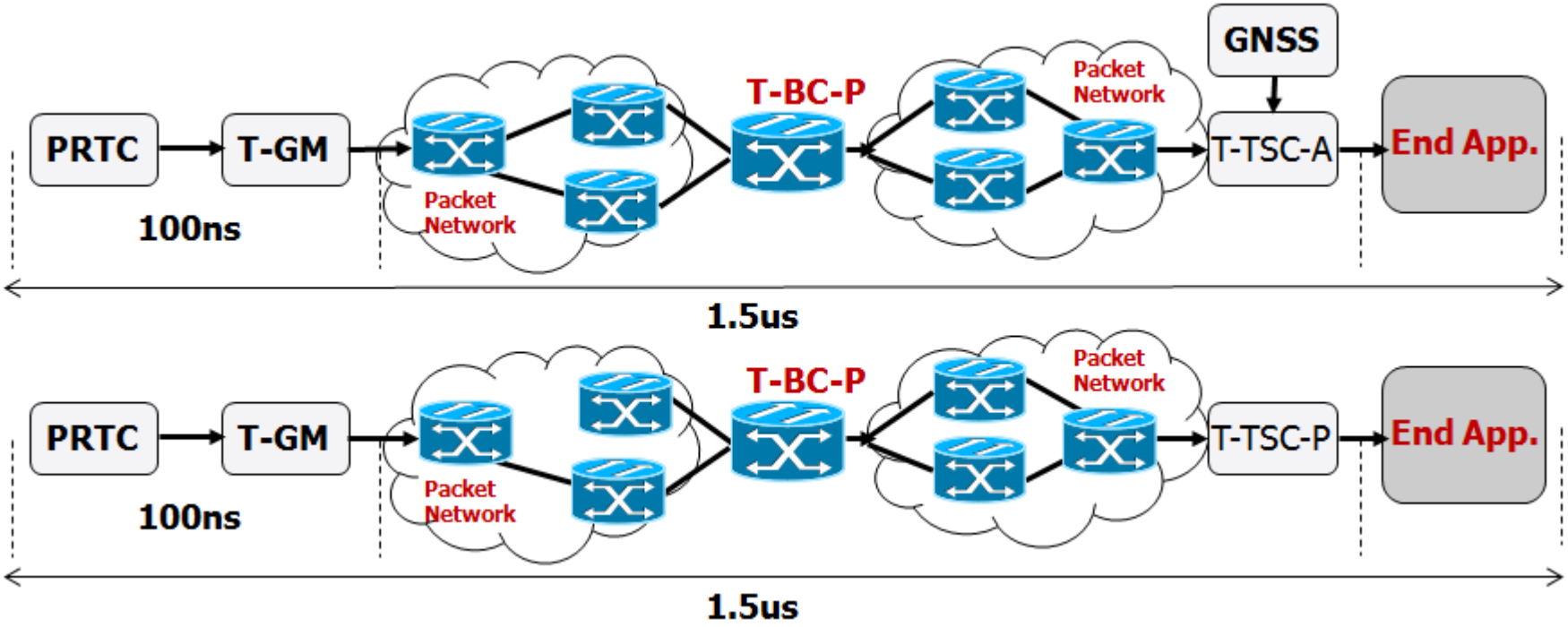
- Two types of Ordinary clocks: T-GM (Telecom Grand master, master clock only) and T-TSC (Telecom Slave clock, Slave-Only Ordinary Clock)
- Boundary clock will be used on the first profile, transparent clocks will be added in future version
- One-step and two-step clocks are allowed
- PTP mappings
  - The default mapping for the Time/phase profile is agreed to be IEEE1588-2008 annex F - Transport of PTP over Ethernet
- Multicast mode
  - For the Ethernet mapping, both the forwardable multicast address 01-1B-19-00-00-00 and the non-forwardable multicast address 01-80-C2-00-00-0E must be used for all PTP messages'
  - The default Ethernet multicast address to be used depends on the operator
- PTP Message types and rates
  - Sync message, Follow-up, Announce, Delay_Request, and Delay_Response
  - Fixed packet rate of 16 packets per second for Sync, Delay_Req and Delay_Resp messages for the case where physical layer frequency support (e.g. Synchronous Ethernet) is used
  - Fixed packet rate of 8 packets per second for Announce message

G.8275.1 - Alternate BMCA

- The alternate BMCA in G.8275.1 is based on the default BMCA specified in IEEE 1588
  - It has provisions to allow a manual network planning
- The alternate BMCA allows
  - Multiple Grand Masters
  - Per-port Boolean attribute notSlave.
    - masterOnly is TRUE -> the port is never placed in the SLAVE state
    - masterOnly is FALSE -> the port can be placed in the SLAVE state
  - Per-port attribute localPriority to be used as a tie-breaker in the dataset comparison algorithm
    - Using different values than their default value allows building manually the synchronization network topology
  - The clock attribute priority1 is static
  - The clock attribute priority2 is configurable
  - the clock attributes clockAccuracy and offsetScaledLogVariance must be set to specific values defined in G.8275.1

ITU-T Time/Phase profile G.8275.2

G.8275.2- ITU-T Time/Phase Profile
IEEE-1588 without support from Network



- For the Assisted Partial Support Telecom Time Slave Clock (T-TSC-A) profile where GNSS is co-located with the end application
  - The local GNSS (e.g. GPS) can be used to measure the asymmetry of the network
  - PTP is used as a backup for GNSS failures
- For the Partial Support Telecom Time Slave Clock (T-TSC-P) without the GNSS co-located with the end application, how many nodes in the network?
  - Discussions are on-going at ITU regarding the network topology/architecture, clock requirements, PDV packet selection criteria and network limit
- G.8275.2 profile was consented in February 2016

GNSS= Global Navigation Satellite System

G.8275.2 PTP Options and Configurable Attributes

- Default PTP domain number is 44, range of {44 – 63}
- Two types of Ordinary clocks: T-GM (Telecom Grand master, master clock only) and T-TSC-P/T-TSC-A (Telecom Slave clock)
- Boundary clock are allowed on this profile
- One-step and two-step clocks are allowed
- Unicast mode only
- PTP mappings
  - IEEE1588-2008 annex D - Transport of PTP over User Datagram Protocol over Internet Protocol Version 4
  - IEEE1588-2008 annex E - Transport of PTP over User Datagram Protocol over Internet Protocol Version 6
- PTP Message types and rates
  - Sync /Follow-up – min rate: 1 packet per second, max rate: 128 packets per second
  - Delay_Request/Delay_Response – 1 packet per second, max rate: 128 packets per second
  - Announce – min rate: 1 packet per second, max rate: 8 packets per second
  - Signaling messages – no rate is specified
- Unicast Negotiation per G.8265.1

G.8275.2 - Alternate BMCA

- The alternate BMCA in G.8275.2 is based on G.8275.1 ABMCA
  - It has provisions to allow a manual network planning
- G.8275.2 alternate BMCA adds
  - Signal Fail: defines 2 types of Packet Time Signal Fail (PTSF): PTSF-lossSync and PTSF-unusuable
- Several aspects regarding the setup of the protocol in the network are still for further study
  - Architectures that imply re-arrangements of the synchronization direction
  - Architectures that include clocks with multiple PTP ports
  - Ports not in Master state that provides synchronization services

ITU-T Q13 Work in Progress

- G.8273.3. Telecom Transparent Clock
- G.8273.4 will also include the requirements for T-TSC-P (Partial Support Telecom Time Slave Clock) and T-BC-P (Partial Support Telecom Boundary Clock)
  - Original G.8273.4 only included the requirements for APTSC (assisted Partial Time support slave clock)
  - Now renamed to”Timing characteristics of partial timing support telecom boundary clocks and telecom time slave clocks”

IEEE 1588 Update

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**
- Five sub committees have been created to focus on several aspects of the technical work
  - Architecture
  - Upkeep
    - Upkeep and architecture are now merged
  - High Accuracy
  - Management
  - Security
- Each sub committee meets once or twice a month via conference call
  - A charter and a requirements document have been created for each sub-committee
- Plan to go to letter ballot mid 2017

High Accuracy (HA)

- Working on a set of options to enable HA using IEEE 1588
  - The technology is based on the CERN White Rabbit (WR) implementation
  - Targets sub ns of accuracy
- HA work
  - Optional features to be added to the current IEEE 1588 standard
  - HA profile defined in the IEEE 1588 standard
  - Other SDOs may define different profiles using the HA options
- High Accuracy is achieved by
  - Physical Layer syntonization (L1SynOp) used for precise round trip measurement
  - Measurement and calibration of asymmetry

Security

- Working on a set of options to enable security in IEEE 1588
- Security work
  - Security requirements for IEEE 1588 Standard
    - Based on IETF document “draft-ietf-tictoc-security-requirements”, October 2013
  - P1588 Security Subcommittee Standing Document (DRAFT)
    - Assumptions, approaches, decisions, and text under development are being documented (work in progress)
- Security working considerations
  - Security requirements to be added as optional features to the current IEEE 1588 standard
  - Profiles should define the security options

Architecture/Upkeep

- Working on architecture aspects of IEEE 1588
- Correction of known technical and editorial errors
- Several aspects were included in the architecture work including
  - Architecture requirements for IEEE 1588 Standard
  - Re-writing of Clause 6 to clarify Media dependent and Media independent layers
  - Profile identification

Management

- Annex M was created for Performance Monitoring Options
- Working on data modeling and MIB structure aspects
- Exploring YANG models for IEEE 1588
- Working on a single IEEE 1588 MIB

References

ITU-T Standards (Frequency)

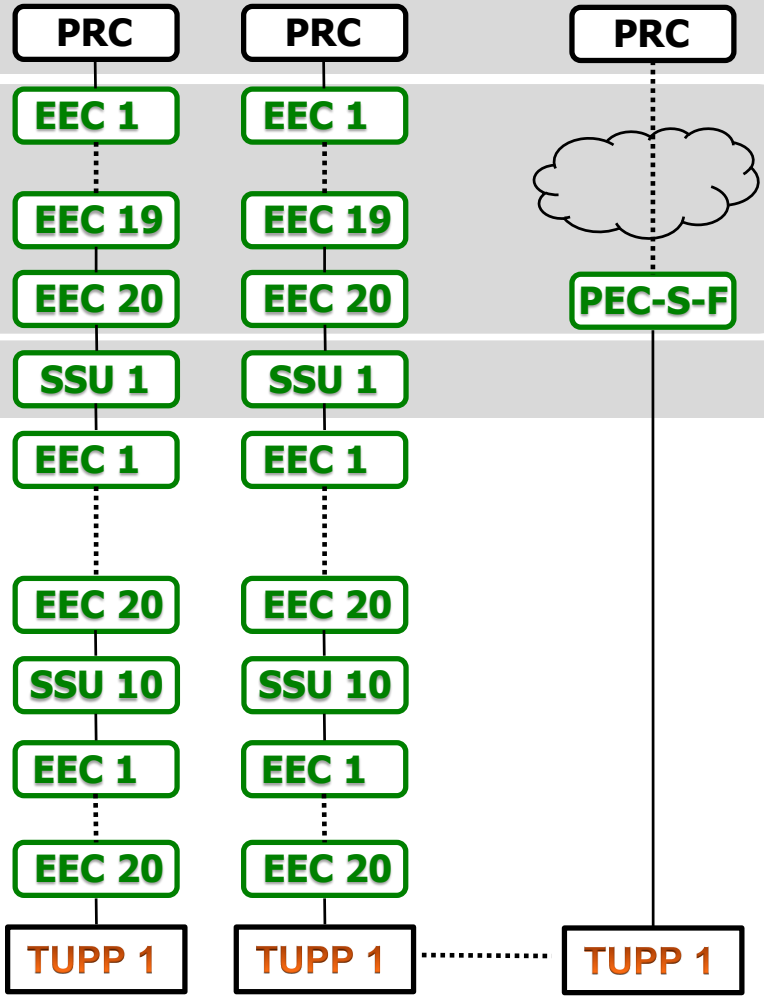
ITU-T Clock Hierarchy for Frequency (G.8261)

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

Equipment slave clocks
- Defined in ITU-T recommendation G.8262 (EEC) & G.8263 (PEC)

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.8261
- Consists of 1 PRC followed by 20 EECs, followed by SSU
- The maximum number of SSUs is 10
- Maximum number of clocks is 60

PRC – Primary Reference Clock
SSU - Synchronization Supply Unit
EEC – synchronous Ethernet Equipment Clock
PEC – Packet Equipment Clock
TUPP – Tributary Payload Processor

ITU-T Standards (SDH/PDH)

ITU-T Clock Hierarchy (G.803)

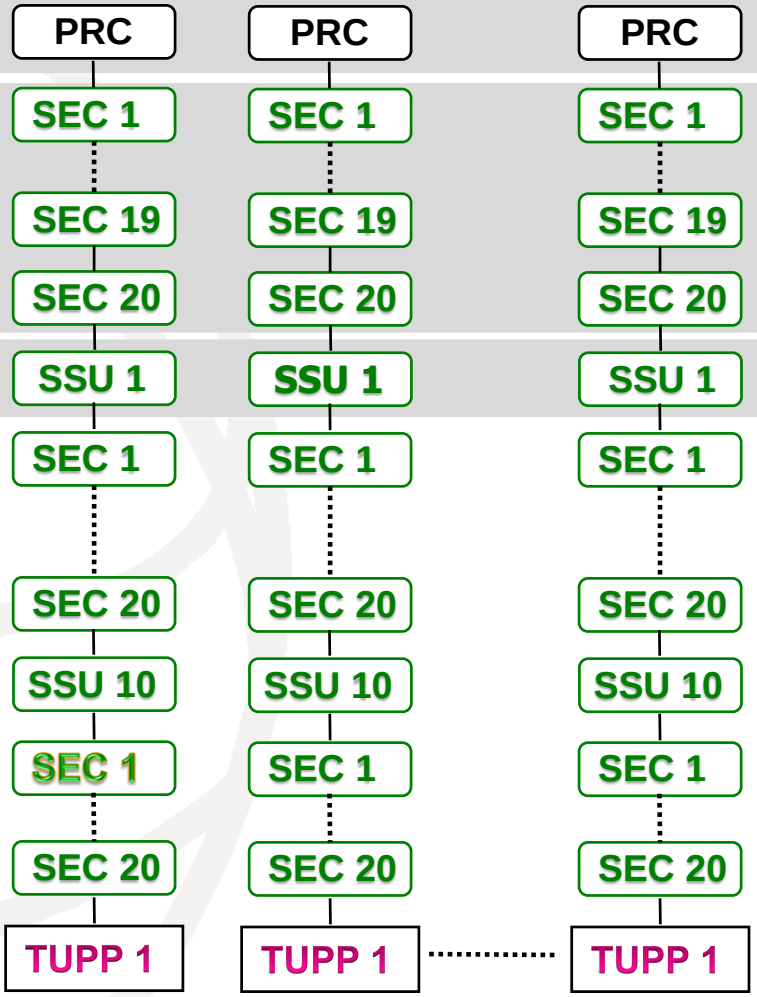
Highest quality clocks : Frequency accuracy < 10^{-11}
- Defined in ITU-T recommendation G.811

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	Not Defined	ST3	Not Defined	SMC	ST4E / ST4
ITU-T Clock	**PRC (G.811)**	**Type II (G.812)**	**Type I (G.812) SSU-A**	**Type V (G.812) SSU-A**	**Type III (G.812)**	**Type VI (G.812) SSU-B**	**PEC-S-F (G.8263)**	**Type IV (G.812) EEC-option2 (G.8262)**	**SEC-option1 (G.813) EEC-option1 (G.8262)**	**SEC-option2 (G.813)**	**Not Defined**
Accuracy	±1x10^{-11} (if maintained to UTC)	±1.6x10^{-8}	Not defined	±1x10^{-7} Not defined for ITU	±4.6x10^{-6}	Not defined	±4.6x10^{-6}	±4.6x10^{-6}	±4.6x10^{-6}	±20x10^{-6}	±32x10^{-6}
Pull-in	Not defined	±1.6x10^{-8}	±1x10^{-8}	±1x10^{-7} Not defined for ITU	±4.6x10^{-6}	Not defined	Not defined	±4.6x10^{-6}	±4.6x10^{-6}	±20x10^{-6}	±32x10^{-6}
BW	Not defined	0.001Hz	0.003Hz	0.1 Hz	0.001 Hz	0.1 Hz	Not defined	3 Hz 0.1 Hz (SONET)	1 – 10 Hz	0.1 Hz	Not defined
Rearrangement MTIE	Not defined	≤ 150ns OT=5000s (ST2) OT=280s (ITU)	≤ 240ns OT=10000s	≤ 1µs OT=64s (TNC) ≤ 240ns OT=10000s (ITU)	≤ 150ns OT=64s (ST3E) OT=280s (ITU)	≤ 240ns OT=10000s	Not defined	≤ 1µs 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 for ST4)
Rearrangement PSL	Not defined	885ns/s PBO (ST2)	7.5µs/s	7.5µs/s Not defined for TNC	885ns/s PBO (ST3E)	7.5µs/s	Not defined	61µs/s 885ns/s (SONET/ITU)	7.5µs/s	885ns/s	61µs/s (Not defined for ST4)
Holdover	Not defined	±1x10^{-10}	2.7x10^{-9}	±1.5x10^{-9}	±1.2x10^{-8}	3x10^{-8}	Optional or ±1.2x10^{-8}	±3.9x10^{-7}	2x10^{-6}	4.6x10^{-6}	Not defined
Holdover Drift at const. temp	Not defined	±1.16x10^{-15} (±0.1ppb/day)	±2.3x10^{-15} (±0.2ppb/day)	±1.16x10^{-14} (±1ppb/day)	±1.16x10^{-14} (±1ppb/day)	±2.3x10^{-13} (±20ppb/day)	±1.16x10^{-14} (±1ppb/day)	±4.63x10^{-13} (±40ppb/day)	±1.16x10^{-13} (±10ppb/day)	±5.8x10^{-12} (±0.5ppm/day)	Not defined

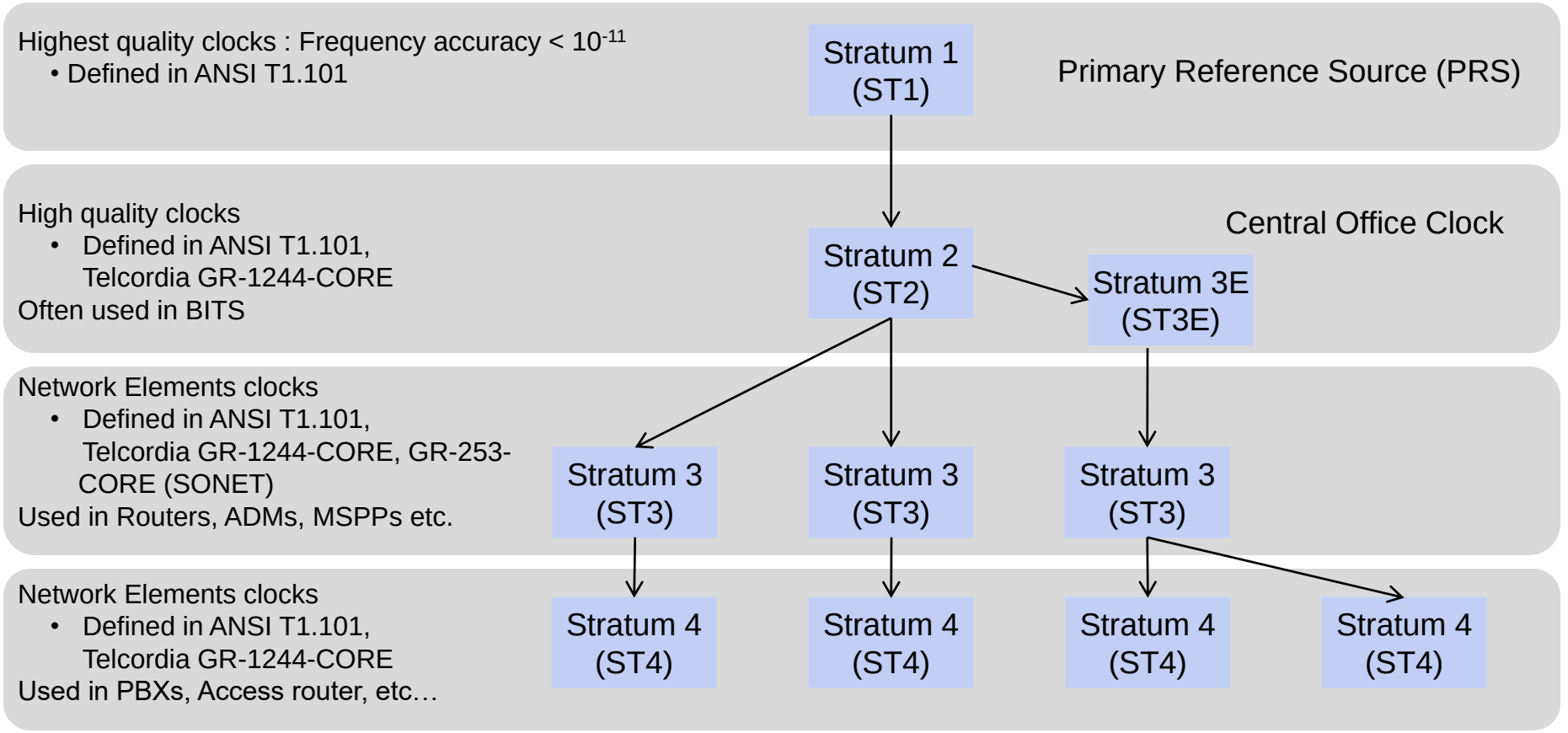
ST = Stratum
SMC = SONET Minimum Clock
TNC = Transit Node Clock
PSL = Phase Slope Limit

SSU = Synchronization Supply Unit
SEC = SDH/SONET Equipment Clock
EEC = synchronous Ethernet Equipment Clock
PEC = Packet-based Equipment Clock

MTIE = Maximum Time Interval Error
BW = Bandwidth
OT=Observation Time
PBO = Phase Build Out

North America Standards (SONET/PDH)

North America Synchronization Hierarchy



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 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.8260, Definitions and terminology for synchronization in packet networks
- ITU T Recommendation G.8261, Timing and synchronization aspects in packet networks.
- Recommendation ITU-T G.8261.1, Packet Delay Variation Network Limits applicable to Packet Based Methods (Frequency Synchronization).
- ITU T Recommendation G.8262, Timing characteristics of Synchronous Ethernet Equipment slave clock (EEC).
- Recommendation ITU-T G.8263, Timing Characteristics of Packet based Equipment Clocks
- ITU T Recommendation G.8264, Distribution of timing through packet networks
- 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 synchronization
- ITU T Recommendation G.8266 , Timing characteristics of packet master clock for frequency synchronization

ITU-T Rec. (Packet Sync – Frequency) work in progress

- ITU T Recommendation G.8262.1, Timing characteristics of an enhanced synchronous Ethernet equipment slave clock (EEC)

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.8272.1, Timing characteristics of enhanced Primary reference time clock
- ITU T Recommendation G.8271.1, Network limits for time synchronization in Packet networks
- ITU T Recommendation G.8273, Framework of phase and time clocks
- ITU T Recommendation G.8273.2 , Timing characteristics of telecom boundary clocks and telecom time slave clocks
- ITU T Recommendation G.8275, Architecture and requirements for packet-based time and phase delivery
- ITU T Recommendation G.8275.1, Precision time protocol telecom profile for phase/time synchronization with full timing support from the network
- ITU T Recommendation G.8275.2 , Precision time Protocol Telecom Profile for time/phase synchronization with partial timing support from the network

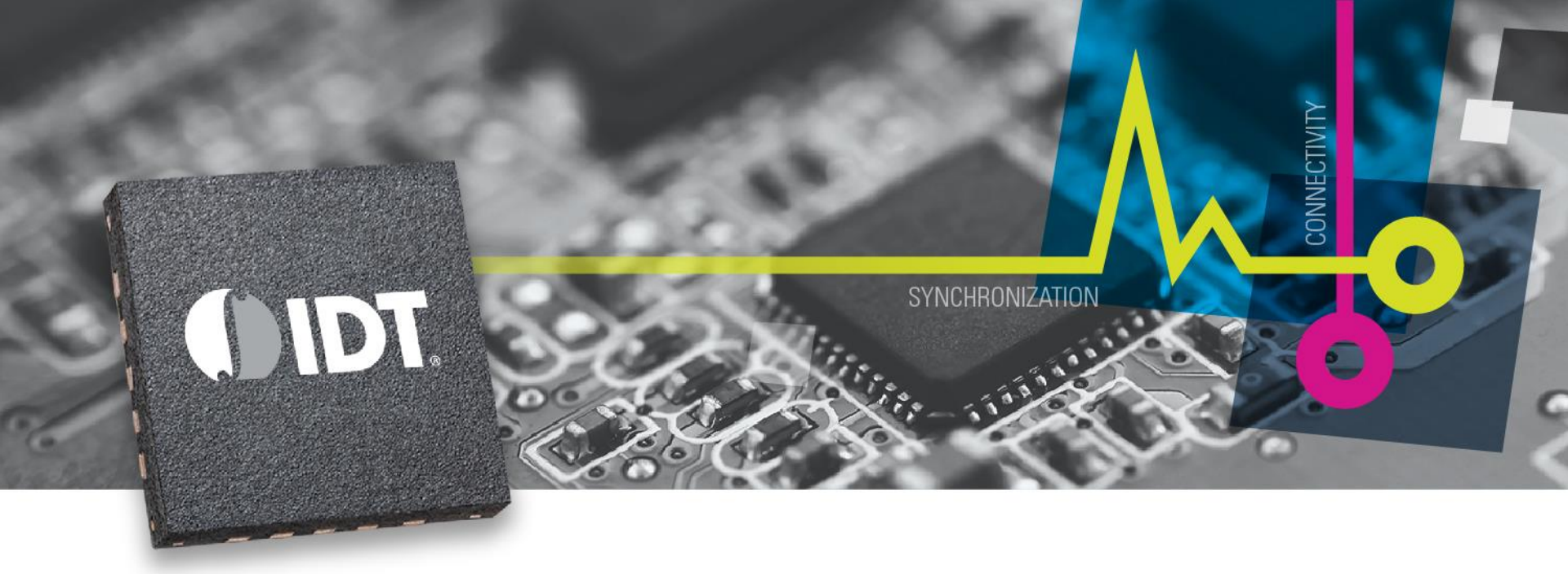
ITU-T Rec. (Packet Sync – Phase/Time) work in progress

- ITU T Recommendation G.8271.2, Network limits for time synchronization in packet networks with partial timing support
- ITU T Recommendation G.8273.1 , Timing characteristics of Telecom Grandmaster clocks
- ITU T Recommendation G.8273.3 , Timing characteristics of telecom transparent clocks
- ITU T Recommendation G.8273.4 , Timing characteristics of assisted partial timing support slave clocks (APTSC)
- ITU T G.Sup, Simulations of transport of time over packet networks

ITU-T profiles for IEEE 1588 White Paper

- White paper on the ITU-T profiles can be found at the IDT web site:

  https://www.idt.com/products/clocks-timing/application-specific-clocks/network-synchronization/ieee-1588-and-synchronous-ethernet-clocks/82p33910-1-synchronization-system-ieee-1588



Thank You

Analog Mixed Signal Product Leadership in Growth Markets