IEEE-1588™ Telecommunications Applications

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Telecommunication Synchronization Background

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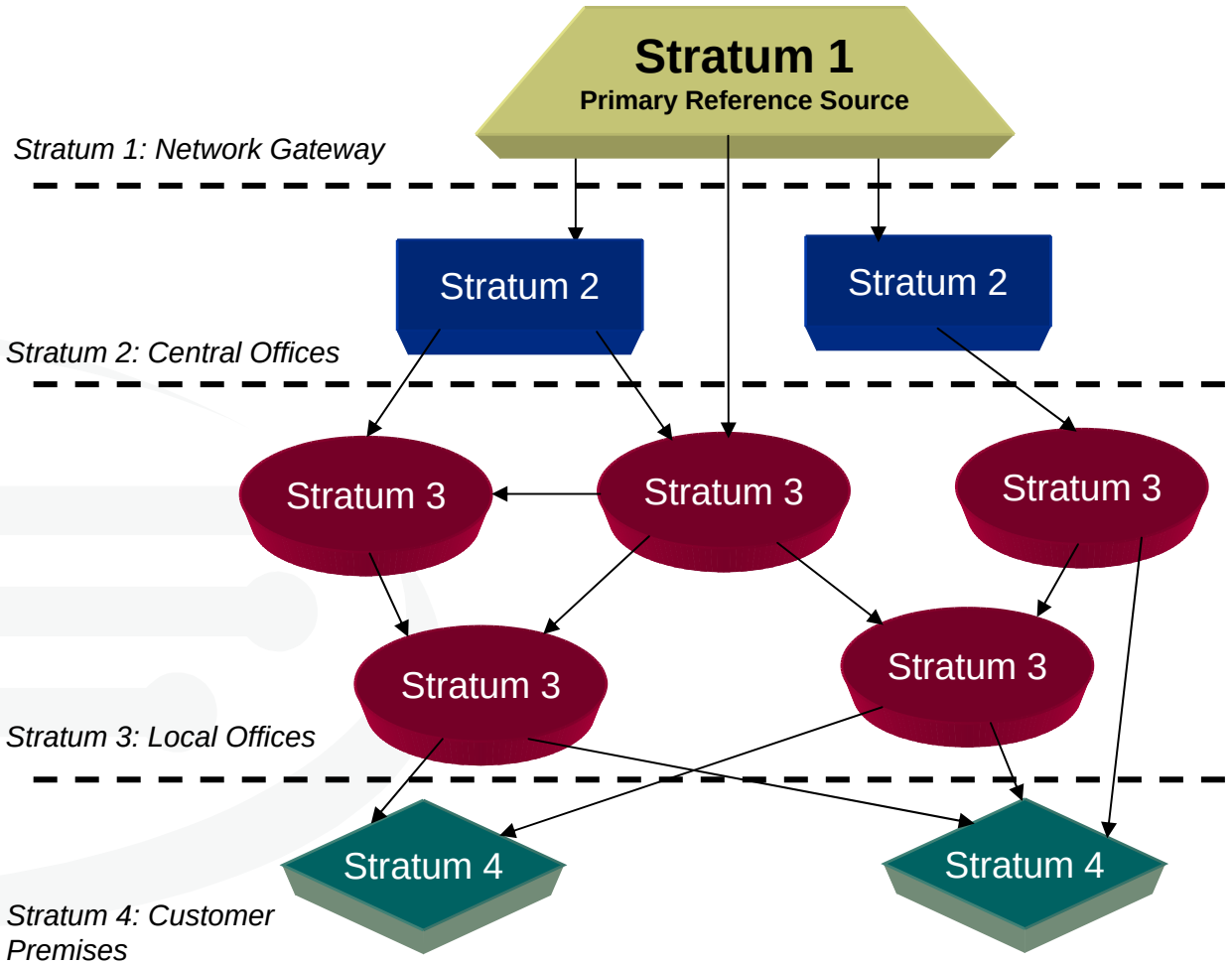
Telecom Synchronization

- Clock quality levels (stratum for North America and Types and Options for the International Telecommunication Union - ITU) are defined by the industry standards organizations to maintain clock quality in the network
- Time sensitive services need synchronization
- Synchronization is important to avoid overflow or underflow of slip buffers, bit errors and other adverse effects
  - ITU-T Recommendation G.822 provides criteria for controlled slip rate

North America Timing Distribution Hierarchy



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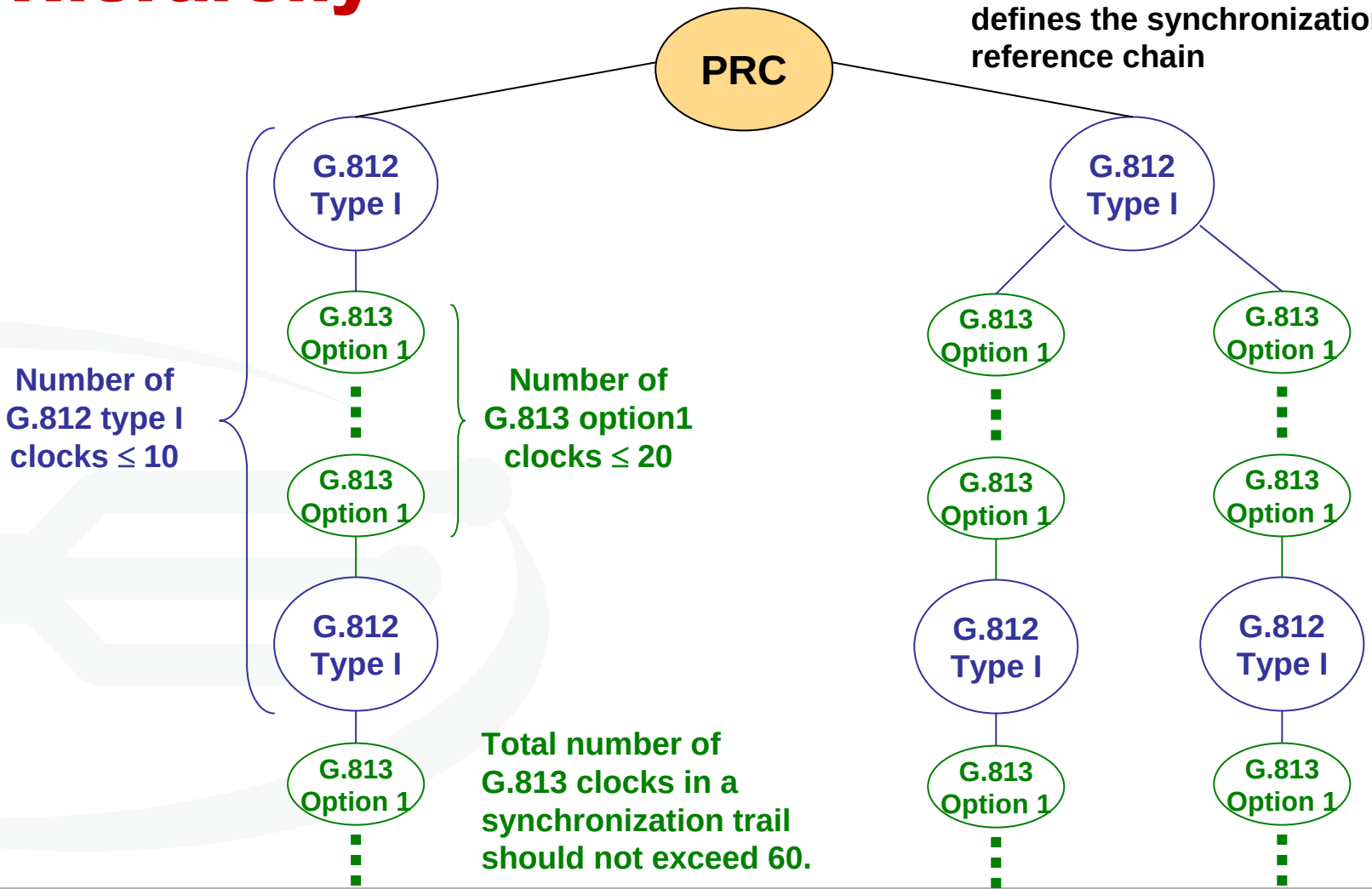
ITU-T SDH Timing Distribution Hierarchy

ITU-T Recommendation G.803 defines the synchronization reference chain



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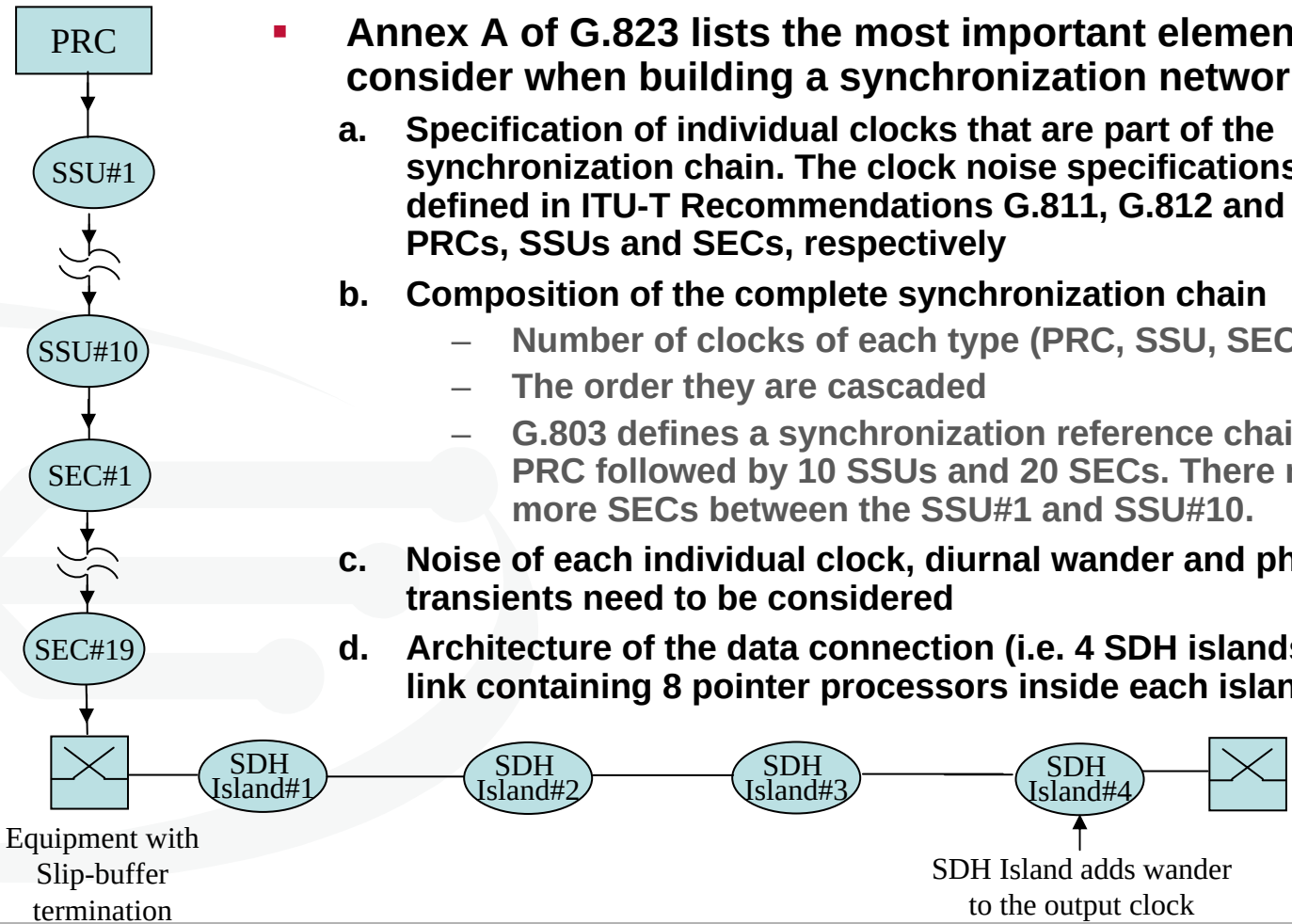
Clock Level

North America Stratum Level	ITU-T Clock Level	Free-run Accuracy	Holdover Stability	Pull-in/ Hold-in range	Wander Filtering	Phase Transient (Re-arrangement)
1 (PRS)	PRC (G.811)	+/- $1x10^{-11}$	N/A	N/A	N/A	N/A
2	Type II (G.812)	+/- 0.016 ppm	+/- $1x10^{-10}$ /day	0.016 ppm	0.001Hz	MTIE < 150ns
Not Defined	Type I (G.812)	N/D	+/- $2.7x10^{-9}$ /day	0.01 ppm	0.003Hz	MTIE < 1µs
3E	Type III (G.812)	+/- 4.6 ppm	+/- $1.2x10^{-8}$ /day	4.6 ppm	0.001Hz	MTIE < 150ns Phase slope 885ns/s
3	Type IV (G.812)	+/- 4.6 ppm	+/- $3.9x10^{-7}$ /day	4.6 ppm	3Hz 0.1Hz (SONET)	MTIE < 1µs Phase slope 61us/s Objective: MTIE < 150n Phase slope 885ns/s
Not Defined	Option I (G.813)	+/- 4.6 ppm	+/- $2x10^{-6}$ /day	4.6 ppm	1 – 10Hz	MTIE < 1µs
SMC	Option 2 (G.813)	+/- 20 ppm	+/- $4.6x10^{-6}$ /day	20 ppm	0.1Hz	MTIE < 1µs Objective mask 150ns Phase slope 885ns/s
4	4	+/- 32 ppm	N/A	32 ppm	No	No Requirement

Standard Requirements

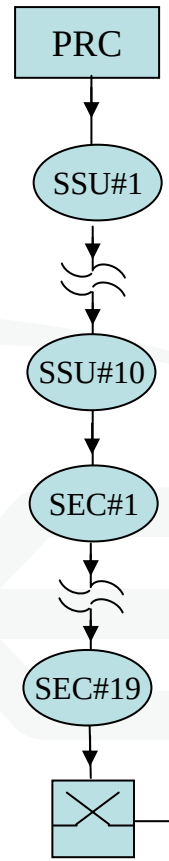
- ITU-T recommendations, G.823 for E circuits and G.824 for T circuits set limits on the magnitude of jitter and wander at network interfaces. The wander may not exceed given values anywhere in the network. Thus, a circuit emulation link, for example, may consume only part of the wander budget
- GSM, WCDMA, and CDMA2000 require frequency accuracy of 0.05 ppm at air interface
- CDMA2000 requires time synchronization at ± 3 μs level (±10 μs worst case)
- WCDMA TDD mode requires 2.5-μs time accuracy between neighboring base stations (i.e. ±1.25 μs of UTC)
  - These requirements are too difficult to achieve without good transparent clocks or boundary clocks in each intermediate node
  - Some cellular operators do have control over the transport network so they could use IEEE1588 compliant switches for achieving time synchronization

Synchronous Network Model

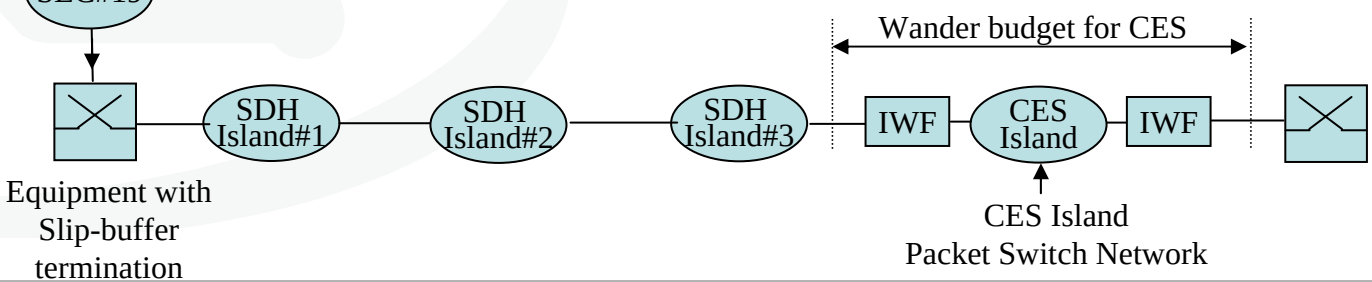


- **Annex A of G.823 lists the most important elements to consider when building a synchronization network**
  - **a. Specification of individual clocks that are part of the synchronization chain. The clock noise specifications are defined in ITU-T Recommendations G.811, G.812 and G.813 for PRCs, SSUs and SECs, respectively**
  - **b. Composition of the complete synchronization chain**
    - **Number of clocks of each type (PRC, SSU, SEC)**
    - **The order they are cascaded**
    - **G.803 defines a synchronization reference chain with 1 PRC followed by 10 SSUs and 20 SECs. There may be 40 more SECs between the SSU#1 and SSU#10.**
  - **c. Noise of each individual clock, diurnal wander and phase transients need to be considered**
  - **d. Architecture of the data connection (i.e. 4 SDH islands on the link containing 8 pointer processors inside each island)**

Converged Network Model



- **ITU-T G.pactiming is studying timing and synchronization aspects in Packet Networks**
  - a. **Specification of individual clocks that are part of the synchronization chain needs to be considered**
    - **Algorithms used to recover clocks in packet networks filter wander, but also generate wander**
  - b. **Noise introduced by Ethernet switches and Routers will add wander to the output clock**
  - c. **Night and day low frequency effects due to load of the packet network**
  - d. **Architecture of the data connection must be considered (i.e. mix of SDH and CES islands)**



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Telecom Applications Examples using 1588

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Requirement scenarios

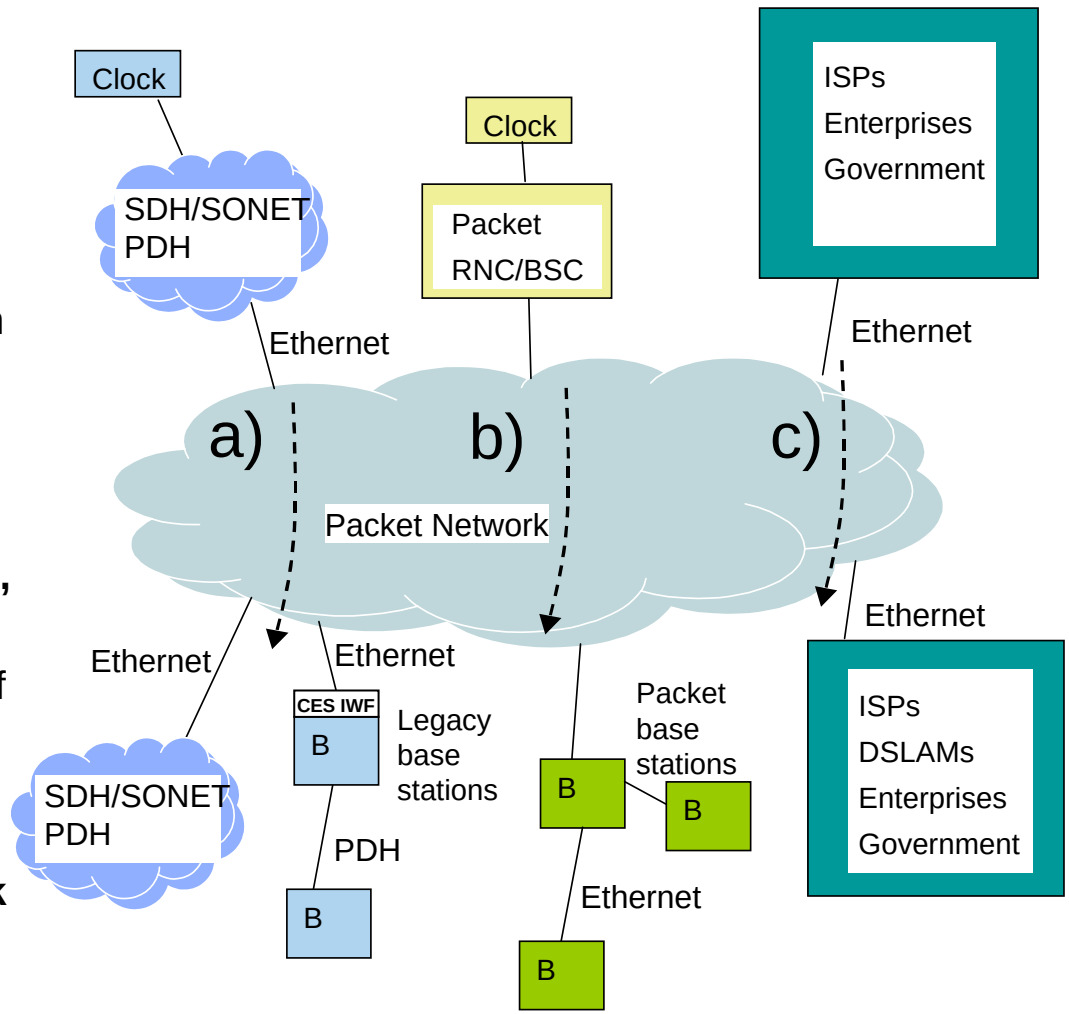
a) **Connecting SDH/SONET/PDH nodes and networks (circuit emulation).**

The connections between SDH/SONET/PDH nodes may be leased from another carrier (e.g. cellular operators usually do not own the transport network). Typical requirements are to meet ITU-T G.823 and G.824.

b) **Connecting nodes, which require synchronization for other reasons, e.g. cellular base stations.**

Typical requirements are 0.05ppm of frequency accuracy.

c) **Connecting offices and nodes of Internet service providers (ISPs), enterprises, government. The bulk of all traffic.**



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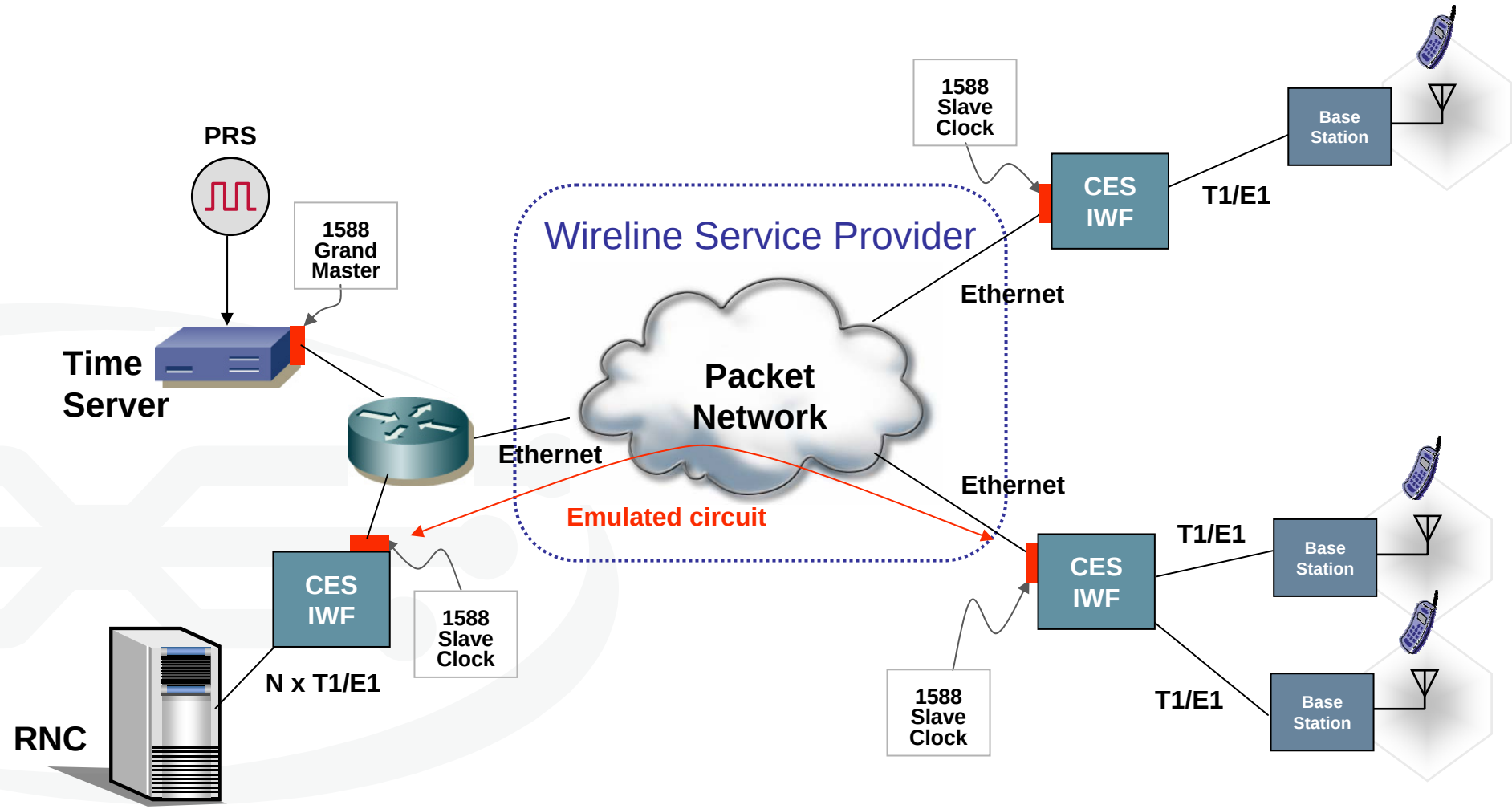
IEEE-1588 used in CES Application



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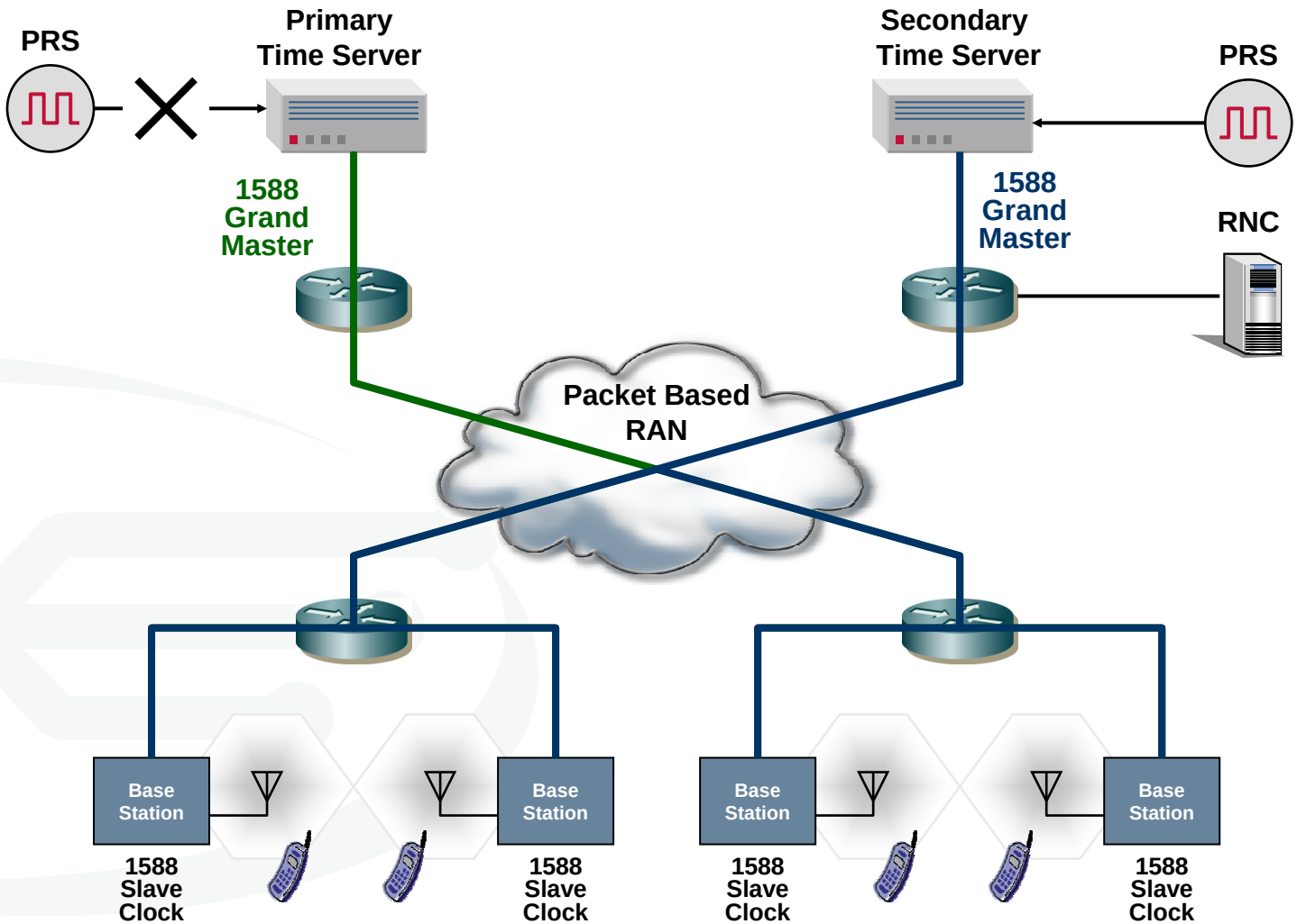
IEEE-1588* used in Wireless Networks



* With proper changes to the current standard

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1588 Standard Work to Support Telecom

IEEE-1588 Issues for Telecom

- IEEE-1588 only allows the values of sync interval to be 1, 2, 8, 16, and 64 seconds
  - It is difficult to maintain performance in a loaded network with sync packet rate of 1pps and an inexpensive oscillator
- IEEE-1588 relies on a symmetric network
- IEEE-1588 does not have provision for redundancy support
  - In telecom applications clocks must be always available
- IEEE-1588 relies on boundary clocks topology
  - Boundary clocks are not available in legacy telecom networks
- IEEE-1588 only supports multicast
- IEEE-1588 Message Format
  - Long PTP messages consuming too much bandwidth

IEEE-1588 Enhancements to Support Telecom

- Enhancements for increased resolution and accuracy
  - Allow shorter sync_intervals
- Extensions to the standard to enable correction for asymmetry
- Extensions to the standard to enable implementation of redundant systems – Fault Tolerant Systems
  - Deal with master clock failure and network failure
- Prevention of errors accumulation in cascaded topologies
  - Deal with boundary clock issues for telecom applications
- Use of Unicast in addition to Multicast
- Short Frame, reduced message format
- Support for QoS

IEEE-1588 Standard Work to Support Telecom

- **Short Frame Format**
  - **There is a consensus to have four short frame messages**
    - **Short Sync Message**
    - **Short Follow-up Message**
    - **Short Delay_Req Message**
    - **Short Delay_Resp Message**
  - **The short frame protocol allows shorter sync_intervals**
  - **The short frame protocol supports a mixed of short and long messages**
  - **The current long frame format is still used for the Best Master Clock algorithm and also to allow slaves to find the address and status of available masters**
  - **The existing Delay Request and Delay Response messages no longer need to be transmitted**
  - **The short messages give the same timing information as the long messages of the existing standard and use the same timestamp format**
  - **The short frame protocol allows the slave to vary the rate at which it receives time information according to its needs**

IEEE-1588 Standard Work to Support Telecom cont'd

- **Fault Tolerant**
  - **There are 3 proposals**
    - **Two slave centric proposals and one master centric proposal**
  - **Fault Tolerant Goals**
    - **The fault of any single network element can not cause slaves to experience a sudden phase change.**
    - **A faulty grand master should be detected and replaced rapidly by another grand master.**
    - **Switching from one grand master to another should not result in a significant phase step at the slaves**
  - **Fault Tolerant subcommittee is working on a single proposal that aligns all the 3 proposals**

Summary

- The interest on IEEE1588 in the Telecom Industry is growing
- Several applications within Telecom can benefit from a Precision Clock Synchronization Protocol like IEEE1588
- The work in IEEE1588 to support Telecom is progressing
  - Short Frame Format is stable
  - Fault Tolerant work is on going
  - Still several issues that need work
    - Issues must be resolved in a timely matter
    - It should be avoided (as much as possible) to add complex functionality to the standard

Acronyms

- **PRC** Primary Reference Clock
- **PRS** Primary Reference Source
- **SDH** Synchronous Digital Hierarchy
- **SEC** SDH Equipment Clock
- **SSU** Synchronization Supply Unit
- **PDH** Plesiochronous Digital Hierarchy
- **GSM** Global System for Communications
- **CDMA** Code Division Multiple Access
- **WCDMA** Wide-band CDMA
- **TDD** Time Division Duplex
- **RNC** Radio Network Controller (WCDMA)
- **BSC** Base Station Controller (GSM)
- **DSLAM** Digital Subscriber Line Access Multiplexer

Thank you!

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