IEEE-1588™
Telecommunications Applications

Silvana Rodrigues
Phone: +1 613 2707258
silvana.rodrigues@zarlink.com
http://timing.zarlink.com/

Antti Pietilainen
Phone: +358(0)718036660
antti.pietilainen@nokia.com
http://www.nokia.com
AGENDA

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Telecommunication Synchronization Background
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

Stratum 1: Network Gateway

Stratum 2: Central Offices

Stratum 3: Local Offices

Stratum 4: Customer Premises
ITU-T Recommendation G.803 defines the synchronization reference chain

Number of G.812 type I clocks ≤ 10

Number of G.813 option 1 clocks ≤ 20

Total number of G.813 clocks in a synchronization trail should not exceed 60.
## Clock Level

<table>
<thead>
<tr>
<th>North America Stratum Level</th>
<th>ITU-T Clock Level</th>
<th>Free-run Accuracy</th>
<th>Holdover Stability</th>
<th>Pull-in/ Hold-in range</th>
<th>Wander Filtering</th>
<th>Phase Transient (Re-arrangement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (PRS)</td>
<td>PRC (G.811)</td>
<td>+/- 1x10^-11</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Type II (G.812)</td>
<td>+/- 0.016 ppm</td>
<td>+/- 1x10^-10/day</td>
<td>0.016 ppm</td>
<td>0.001Hz</td>
<td>MTIE &lt; 150ns</td>
</tr>
<tr>
<td>Not Defined</td>
<td>Type I (G.812)</td>
<td>N/D</td>
<td>+/- 2.7x10^-9/day</td>
<td>0.01 ppm</td>
<td>0.003Hz</td>
<td>MTIE &lt; 1μs</td>
</tr>
<tr>
<td>3E</td>
<td>Type III (G.812)</td>
<td>+/- 4.6 ppm</td>
<td>+/- 1.2x10^-8/day</td>
<td>4.6 ppm</td>
<td>0.001Hz</td>
<td>MTIE &lt; 150ns Phase slope 885ns/s</td>
</tr>
<tr>
<td>3</td>
<td>Type IV (G.812)</td>
<td>+/- 4.6 ppm</td>
<td>+/- 3.9x10^-7/day</td>
<td>4.6 ppm</td>
<td>3Hz 0.1Hz (SONET)</td>
<td>MTIE &lt; 1μs Phase slope 861ns/s Objective: MTIE &lt; 150n Phase slope 885ns/s</td>
</tr>
<tr>
<td>Not Defined</td>
<td>Option I (G.813)</td>
<td>+/- 4.6 ppm</td>
<td>+/- 2x10^-6/day</td>
<td>4.6 ppm</td>
<td>1 – 10Hz</td>
<td>MTIE &lt; 1μs</td>
</tr>
<tr>
<td>SMC</td>
<td>Option 2 (G.813)</td>
<td>+/- 20 ppm</td>
<td>+/- 4.6x10^-6/day</td>
<td>20 ppm</td>
<td>0.1Hz</td>
<td>MTIE &lt; 1μs Phase mask 150ns Phase slope 885ns/s</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>+/- 32 ppm</td>
<td>N/A</td>
<td>32 ppm</td>
<td>No</td>
<td>No Requirement</td>
</tr>
</tbody>
</table>
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)

SDH Island adds wander to the output clock
ITU-T G.8261 timing is studying timing and synchronization aspects in Packet Networks

- 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

- Noise introduced by Ethernet switches and Routers will add wander to the output clock

- Night and day low frequency effects due to load of the packet network

- Architecture of the data connection must be considered (i.e. mix of SDH and CES islands)
Telecom Applications
Examples using 1588
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.
IEEE-1588 used in CES Application

Wireline Service Provider

Packet Network

Emulated circuit

Time Server

PRS

1588 Grand Master

CES IWF

N x T1/E1

RNC

1588 Slave Clock

1588 Slave Clock

1588 Slave Clock

Base Station

Base Station

Base Station

CES IWF

CES IWF

CES IWF

T1/E1

T1/E1

T1/E1

Ethernet

Ethernet

Ethernet
IEEE-1588* used in Wireless Networks

* With proper changes to the current standard
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!