Jitter and Wander Testing in High-Speed Telecom Networks

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ITSF 2006
Agenda

- Network evolution
- Jitter and wander aspects
- Application scenarios
- Case study
- Conclusion
Evolution of optical transport data rates

Increase of data rate by 4 and by 10

Year: CY82, CY86, CY92, CY97

Data rates:
- 155M
- 622M
- 1G
- 2.5G
- 10G
- 40G
- 100GE

Technologies:
- SDH/SONET
- Ethernet
- OTN G.709

Hardware Ports:
- 10BASE
- 100BASE
- 1GE
- 10G
- 40G
- 100GE

Source: Infonetics Research, February 2006
Combining TDM and packet switched networks

High-speed service 10GE:
WAN (9.9G), WAN OTN (10.7G), LAN (10.3G), LAN OTN (11.1G)
Transport of IP over optical medium

Services
- 3 play

Routing
- IP
- Ethernet
- GFP
- PPP

Transport
- VC/LCAS
- NG SDH/SONET
  - CC
- OTN

Physical
- Optical medium (WDM, dark fiber)
SDH network synchronization – well implemented

- GPS controlled PRC
- SSU (TNC or LNC)
- SEC (G.811)

- OTN is not required to transport synchronization
- OTN allows the transport of synchronization via SDH client connections
Timing is distributed from PRC to IWF across the packet switched network

Ethernet switches are part of the synchronization network
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Difference between jitter and wander

Wander range

Jitter range

10 Hz

Wander in ns

Observation time

MTIE

TIE max

TIE min

TIE at t_end

Jitter in UI

+ peak

- peak

peak

peak

Measurement time

Time

Frequency

MTIE
### Jitter/wander generation, tolerance and transfer

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.810</td>
<td>Definitions and terminology</td>
</tr>
<tr>
<td>G.811</td>
<td>Primary Reference Clocks (PRC)</td>
</tr>
<tr>
<td>G.812</td>
<td>Synchronisation Supply Unit (SSU)</td>
</tr>
<tr>
<td>G.813</td>
<td>SDH Equipment Slave Clocks (SEC)</td>
</tr>
<tr>
<td>G.823</td>
<td>PDH Network Interfaces (2 Mb/s)</td>
</tr>
<tr>
<td>G.824</td>
<td>PDH Network Interfaces (1.5 Mb/s)</td>
</tr>
<tr>
<td>G.825</td>
<td>SDH Network Interfaces</td>
</tr>
<tr>
<td>G.8251</td>
<td>OTN Network Interfaces</td>
</tr>
<tr>
<td>G.783</td>
<td>SDH Equipment Functional Blocks</td>
</tr>
</tbody>
</table>
Rec. for synchronization over packet networks

**ITU-T G.8261**

Timing and synchronization in packet networks

- TDM over packets needs to be compliant to existing TDM timing standards

**ITU**

physical layer (layer 1)

vs.

in-band (layer 2)

**IEEE 1588**

Precision Clock Synchronization Protocol

- Precision Time Protocol (PTP) is able to synchronize distributed clocks with an accuracy of less than one microsecond

**IETF RFC1305**

Network time protocol (NTP) – accuracy in ms

**IETF RFC2030**

Simple network time protocol (SNTP) – accuracy in s
ITU-T Recommendations for test equipment

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.171</td>
<td>Jitter and wander measuring equipment for PDH</td>
</tr>
<tr>
<td>O.172</td>
<td>Jitter and wander measuring equipment for SDH</td>
</tr>
<tr>
<td>O.173</td>
<td>Jitter measuring equipment for OTN</td>
</tr>
</tbody>
</table>

Generator

Analyzer (jitter, wander)

 ext. ref.

ext. sync.
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## Jitter and Wander Applications

<table>
<thead>
<tr>
<th>Jitter/wander</th>
<th>SDH/SONET/PDH OTN (wander not required)</th>
<th>Ethernet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation</strong></td>
<td>Network</td>
<td>BERT scan (Bathtub curve)</td>
</tr>
<tr>
<td><strong>Tolerance</strong></td>
<td><img src="image1" alt="Tolerance Graph" /></td>
<td>Stressed eye</td>
</tr>
<tr>
<td><strong>Transfer</strong></td>
<td><img src="image2" alt="Transfer Graph" /></td>
<td>not applicable</td>
</tr>
</tbody>
</table>

### Diagrams:
- Network simulation with BERT scan graph.
- Stressed eye measurement.
- Regenerator and jitter simulation.

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Requirements for wander test equipment

- Generation of wander amplitudes/frequencies
- Analysis of TIE, MTIE, TDEV, frequency offset and drift rate
- Built-in masks that comply with ITU-T, Telcordia, ETSI and ANSI
- Sample rates 1/ s, 30/ s, 60/ s, 1000/ s
- Reference input for clock 1.5/ 2/ 5/ 10MHz and data 1.5/ 2Mbs
Commissioning test configurations

- Tests on network element (NE) level prior to installation
- Tests on synchronisation interfaces after installation

Wander generation

Wander tolerance

Wander transfer

NE

Timing reference

STM-N

NE

Timing reference

STM-N

NE

Synch. IF

Timing reference
Acceptance test configurations

- Tests on interfaces handing over timing between telecom networks
- Tests on reference clock sources

### Synchronized configuration

- Timing reference
- Characterization of timing transport

### Non-synchronized configuration

- Timing reference
- Characterization of timing quality
Test configuration for asynchronous signals

Maximum relative time interval error (MRTIE)

Async Clock

±x ppm

Signal Source

e.g. 2Mb/s

Timing reference

Network

Characterization of network wander with elimination of clock offset ±x ppm

TIE with frequency offset
Offset corrected TIE
Wander on OTN network elements

- The OTN physical layer is not required to transport network synchronization
- There is no need for specification of network wander limits (ITU-T G.8251)
- Our recommendation: Wander measurement at OTU interfaces to ensure proper operation at SDH interfaces

Mapping process
Wander on OTU clock leads to byte stuffing which introduces wander into recovered 10G

Long term OTUk bit rate shift leads to adjustments of 10G depending on the filling level of the FIFO used for bit rate adaption
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Examples for wander analysis

<table>
<thead>
<tr>
<th>MOD SRC</th>
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<table>
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<th>TIE</th>
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White noise

Frequency offset
Examples for wander analysis

- **Sine 0.1 Hz**
- **Sine + noise + offset**

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<tr>
<th>TIE</th>
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![Graphs showing TIE and MTIE/TDEV for different sine wave scenarios](image)
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Conclusion

- Carriers try to converge new and legacy services on to a single platform, a packet switched network such as metro Ethernet. This will allow them to reduce both capital and operating costs.
- Synchronization is essential to enable real-time and high-speed transmission for telecom networks.
- As telecom networks migrate to packet networks, the debate is about how the “synchronization” is passed from one network node to another.
- Several standard bodies are working on that topic.
- Carriers need to evaluate and decide whether “in-band” or “physical layer” is the preferred technique to transport the timing information.
Q & A

Thank you for your attention

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