Choices for 5G
Data center Synchronization

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Topics

• Synchronisation scenarios
• Key performance parameters
• Choices of frequency references
Application Scenarios

• OCP – TAP community is defining the DC profile for IEEE – 1588
  - HRM

• 5G works as “TSN Bridge” for TSN applications
  - IEEE802.1-AS – 2020 with requirements

• 5G CU/DU functionality to move to data centers
Key parameters for synchronization

- **Dynamic Error** => Filtered network noise + High Pass component of Oscillator error

- **Holdover** => Ability to keep the output error within certain limits for certain time when references are lost

Dynamic Error

Dynamic Synchronisation

- Radios (overall) – 40 to 400ns According to IEEE 802.1CM and ITU-T G.8271 specifications
  - The network side of the radio expects for 5-20ns error

- Switches deploy T-BCs Type C/D – 5ns to 15ns error
  - Front Haul requirements demand T-BC – Type C and D like clocks

- CU/DU equipment - T-BC with Assisted / Partial or Fully supported clocks – 5ns ~20ns
  - Multi-Band GNSS systems achieve ~20ns error values

- GM clocks – Uses GNSS reference - ~20ns
  - Multi-Band GNSS systems achieve ~20ns error values

- Loop bandwidth requirements of 10-75mHz on G.8262 like networks
  - Higher bandwidth for G.8262.1

- Loop bandwidths of 50-100mHz proposed by G.8273.2 like clocks
  - Assumes physical layer support

- Assisted
  - GNSS inputs require 10-30mHz filter

- Partial
  - Assumes no physical layer support - <1mHz loop bandwidth common

- GMs have GNSS references
  - GNSS inputs require 10-30mHz filter

Requires an oscillator with ~0.1ppb/degC frequency sensitivity
## Choices of references

- For handling dynamic performances

<table>
<thead>
<tr>
<th>OCXO / HTCXO</th>
<th>TCXOs</th>
<th>Hybrid TCXOs</th>
<th>Mini-OCXOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Vs Temperature Performance</td>
<td>±10 ~100 ppb (-40 to 105°C)</td>
<td>±5 - ±20ppb (40 to 85°C)</td>
<td>±8 ppb (40 to 95°C)</td>
</tr>
<tr>
<td>Footprint</td>
<td>7 x 5 mm</td>
<td>7 x 5 mm</td>
<td>9 x 7 mm</td>
</tr>
<tr>
<td>Frequency Sensitivity to temperature</td>
<td>5-10 ppb/°C</td>
<td>0.1 ppb/°C</td>
<td>0.1 ppb/°C</td>
</tr>
</tbody>
</table>
Holdover

\[ x(t) = x_o + (f_o + \text{average}(\Delta f_{\text{env}} + \Delta f_{\text{HT}} + \Delta f_{\text{RW}})) \cdot t + \frac{1}{2} \Delta f_{\text{age}} \cdot t^2 \]

- \( x_o \): Initial phase offset
- \( f_o \): The initial fractional frequency offset (ppb)
- \( \Delta f_{\text{env}} \): Sum total of the changes in frequency (ppb) due to environmental factors (including temperature, input voltage, output loading, pressure, humidity, acceleration etc.)
- \( \Delta f_{\text{HT}} \): Effect of hysteresis on holdover
- \( \Delta f_{\text{RW}} \): Random frequency noise not associated with environmental effects or long term aging
- \( \Delta f_{\text{age}} \): The long term change in frequency over time (ppb/day)

Choices of references

- For handling Holdover

<table>
<thead>
<tr>
<th>OCXO /HTCXO</th>
<th>Mini-OCXOs</th>
<th>SMART OCXOs</th>
<th>PPS DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Vs Temperature Performance</td>
<td>±5 ppb (40 to 85 °C)</td>
<td>±0.5 to 3 ppb (40 to 85 °C)</td>
<td>±0.25 ppb (40 to 85 °C)</td>
</tr>
<tr>
<td>Footprint</td>
<td>7 x 5 mm</td>
<td>25 x 22 mm</td>
<td>25 x 22 mm</td>
</tr>
<tr>
<td>Ageing performance</td>
<td>0.35 ppb/day</td>
<td>0.2 ppb/day</td>
<td>0.002 ppb/day</td>
</tr>
<tr>
<td>Holdover Performance (1.5us)</td>
<td>3-4 Hours</td>
<td>6-8 Hours</td>
<td>24 hours</td>
</tr>
</tbody>
</table>
Summary

• New applications drive high-performance synchronization systems

• Dynamic performance and Holdover are key parameters

• Depending on the requirements, a variety of synchronization reference technologies are available to select from
THANK YOU