Why PTP?

STANDARDS BASED

ACCURATE
Great than 1 μSec Accuracy
Lengthy Holdover
Quantifiable Performance

DISTRIBUTABLE
Ethernet Based
No Special Cabling
Simple Deployment for any Environment

SECURE
Defined Fail Over Parameters
Alarming on Errors
Substation Hardened

Synchrophasor Clocking Source & Evolution for Other Substation Devices
Types of PTP Clocks

- **Grand Master**: Master Time Source for All Clocks
- **Boundary**: Best Master Clock Algorithm Allows Grand Master Redundancy
- **Ordinary**: Clock Distribution Over WAN (Typically End to End)
- **Ordinary**: Local Master for Ordinary Clocks
- **Ordinary**: Transparent Clocks Distribute Clock Signal and Correct Time Stamps
- **Ordinary**: Synchronized End Devices (Typically Peer to Peer)
Remote Synchronization Source

Hub to Sub - Standards Based 1588 Telecom Profile Distribution

Local Source
Substation Hardened – Rb Holdover

Transparent Clock
Distribution to All Devices

Sub to Device - Standards Based 1588 Power Profile Distribution

Fiber Based Ethernet Cabling
Whenever Possible

Full Redundancy
This is only half of the picture!
Typical Substation Clocking Distribution with Redundancy
Noise Impairment Tests

- Noise Injection / IP Packet interference

**PMU to Sub PDC - Standard Configuration**

5PMU1
- P1
- P2
- P3

P2
- P4
- P5

Ethernet Switch
- P9

P9
- P1

Ethernet Switch with 1588
- P5
- P7

P1
- P2

PDC-1

5PMU4
- P1
- P2

P1
- P15

Router with Integrated Switch
- P3

PMU to Sub PDC – Signal Impairment Configuration

5PMU1
- P1
- P2
- P3

P2
- P4
- P5

Ethernet Switch
- P9

P9
- P1

Ethernet Switch with 1588
- P5
- P7

P1
- P2

PDC-1

5PMU4
- P1
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P1
- P15

Router with Integrated Switch
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Noise Impairment Device

P3
Observations – Timing functions (GPS, IRIG-B, and IEEE 1588)

- Several GPS-synchronized clocks providing timing accuracy better than 1 us (mostly on the order of 0.1 us)
- Some clocks did not update time-quality bits in IRIG-B timing data after loss of GPS input. Similarly, for IEEE 1588 PTP.
- In the absence of GPS input, clock drifts on the order of $10^{-7}$ to $10^{-9}$ were observed from different clocks.
  - Typical commercial products
    - $10^{-9}$ is a drift of 4 us in about an hour
    - $10^{-7}$ is a drift of 26 us in about 4 minutes (Bad Time)
  - Synchrophasor permissible TVE of 1% ~ 26.5 us
- Other 1588 PTP (precision time protocol) test results
  - Typical accuracy of 0.1 to 0.5 us has been observed.
  - Any delay in network communication can translate to delay in Transparent Clock when not compensated.
  - Some Slave clocks assume transmission delay is the same in both directions (usually OK, but not always)
Timing Latency & Fluctuation

Application layer

Network protocol stack

Physical layer

msecs of delay and fluctuation

< 100 nsecs of delay and fluctuation

Repeaters & Switches: fluctuations ~100ns to usec

Routers: fluctuations ~ms

Repeater, Switch, or Router
Synchronization Details (continued)

IEEE-1588 Code

Network protocol stack & OS

Sync detector & timestamp generator

Physical layer

Master clock receives:
- Delay_Req message

Master clock sends:
- Delay_Resp message

Time at which a Delay_Req message passed the Timestamp Point \( (t_4) \)

Timestamp Point
LN – STIM identified to set time and provide time synchronization in a substation

<table>
<thead>
<tr>
<th>Class</th>
<th>Accuracy</th>
<th>Function/phase error</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>± 1 ms</td>
<td>Event timing</td>
</tr>
<tr>
<td>T2</td>
<td>± 0.1 ms</td>
<td>Zero Crossing / Sync Check</td>
</tr>
<tr>
<td>T3</td>
<td>± 25 μs</td>
<td>32’ at 60Hz / 27’ at 50 Hz</td>
</tr>
<tr>
<td>T4</td>
<td>± 4 μs</td>
<td>5’ at 60Hz / 4’ at 50 Hz</td>
</tr>
<tr>
<td>T5</td>
<td>± 1 μs</td>
<td>1’ - Synchrophasors</td>
</tr>
<tr>
<td>T6</td>
<td>± 0.1 μs</td>
<td>Available, but not defined yet</td>
</tr>
</tbody>
</table>