Hardware-In-the-Loop Testing of Phasor Measurement Unit using Mini-Full Spectrum Simulator

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October 15, 2016

MTP Stage - 1

Introduction

Overview

1. Theoretical background
2. Literature Survey
3. Proposed Scheme
4. Work Done
5. Plan of work

Why Precise Time?

- Event Reconstruction - 14, Aug, 2003 North America
- Synchro Phasors / WAMS - Geographically separated
- Multi-rate Billing
- Traveling-wave Fault Detection
- Testing and verification of protective devices

What - Basic Requirements

- Reference synchronized to national standard - UTC, Atomic clock
- **Robustness:** Survive contingency, unstable clock
- Should be **automated**, **customizable** and **efficient**
- Not cause system infrastructure overhead.
- **Security:** immune to intrusion & withstand potential attacks

How - can we get it?

There are different sources of accurate time:

1. **Atomic clock**: Ultimate reference, cesium beam oscillator. Costly but longer stable operation
2. **GPS:** US DoD, Started 1980s - NAVSTAR, 1993- full functional, 24 satellites
3. **GLONASS:** 1976 USSR, better than GPS
4. **Standard Radio Transmission:** Oldest time-keeping method, existent since 1920
5. Microwave or Terrestrial Distribution: US, UK & Germany, sensitive to corona

How - can we get it? (continued)

Methods of Time Distribution:

1. Dedicated Timing Signals:
   - 1 Pulse Per Minute (1 PPS):
     - Excellent accuracy 100ns
     - Simple, easy, flexible
     - Ambiguity of 1 year
   - IRIG
     - Inter-Range Instrumentation Group [1956-1970]
     - 7 codes [A - H] & 2 Types [Modulated - Unmodulated]
     - Accuracy range: $10 - 50ns$
     - Currently MOST used method commercially

continued...

How - can we get it? (continued)

Engineering is about: Feasible - Simple - Cheap - Reliable solutions
"Can't we use the same network to timekeep & send data?"

2. Network Time Synchronization:
    - NTP/SNTP:
        - Existing since 1980s
        - Reliable, flexible, simple, cheap, robust
        - Accuracy range: 10 – 100 *ms*
        - Most widely used
    - PTP/IEEE 1588:
        - Extremely accurate
        - 2 modes : Software only & Hardware-aided
        - Accuracy range: 20 – 100 *ns*
        - Slowly replacing NTP, 1 PPS & IRIG-B

Detailed Study

Network Time Protocol

1. Epoch started on 1 Jan, 1972 at 2,272,060,800.0 seconds.
2. 64-bit word length.
3. Stratum, Synchronization Distance & Dispersion.

$$a = T_{i-2} - T_{i-3} \quad \text{and} \quad b = T_{i-1} - T_i$$

$$\delta_i = a - b \quad \text{and} \quad \theta_i = \frac{a + b}{2}$$

Contingency

In case of network disruption, NTP adapts itself to optimum configuration, it uses algorithms like (but not limited to):

- Peer-selection algorithm
- Convergence & Consistency algorithm, minimum filter & minimum average algorithm.
- Agreement algorithm for peer-selection (adaptation of maximum likelihood algorithm)

PTP/ IEEE 1588

- Defined in 2002, standard quotes:
  "IEEE 1588 is designed to fill a niche not well served by either of the two dominant protocols, NTP and GPS. IEEE 1588 is designed for local systems requiring accuracies beyond those attainable using NTP... for applications that cannot bare cost of GPS receivers.."
- Two modes - Software-only & Hardware assisted
- It can be called an enhanced version of NTP.
- Hardware-aided mode - highly accurate: 1 - 10 ns
- CERN is using enhanced PTP with accuracy of 3 *sps*

How is it different than?

- Calculation same as NTP but
- Variable path delay calculated in hardware mode:
  - Transparent Clock
  - Boundry clock
  - Grandmaster clock
- Only one reference (1 grandmaster at a time)
- Proactive delay synching

Case Study

NTP v/s PTP

blahblahsjhkjsdkjsd

NTP v/s PTP (Case-1, link-1 fails)

adslsdflsdf

NTP v/s PTP (Case-2, link-3 fails)

fake fake

NTP v/s PTP (Case-3, link-2 fails)

fakealkds;lksj;oiwejr

NTP v/s PTP (Case-4, Both masters fails)

werwerqwerq

NTP v/s PTP why PTP is preferred

werwesdfsdfs

Conclusion

NTP

- Can work on network of any dimension
- No additional hardware
- No network modification
- Practically no additional cost
- Least possible network overhead
- Simple - cheap - robust - flexible

PTP

- Highly Accurate
- Variable packet delay compensated
- Can handle greater network disruption - Robust
- Reliability is high so mission critical

References

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Thank You