Is NTP A Suitable Timing Source For Grid Applications?

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Outline

- Motivation
- Approach & Research
  - What is NTP & How Does It Work?
  - Strengths & Weaknesses
  - Applications
- Conclusion & Acknowledgements
The Need For Time Agreement
The Grid Is Becoming More Like A WAN

Flow is no longer one way

Generation is not controlled or dispatched

No longer deterministic architecture with pre-known flows

No longer over-provisioned for arbitrary regulations & lack of holistic knowledge

Rely less on experience and intuition and more on computational analytics
...And Situational Awareness of a Distributed WAN Demands Coordination

The North American Electric Reliability Council cited a lack of situational awareness as a contributing factor leading to the 2003 blackout.

Among their recommendations was the installation of time-synchronized data recording and reporting devices.

- Cast a wide net – monitor & capture timestamped state as much as possible
- Analyze rapidly distilling critical info
- Retain all useful data with timestamps for future analysis
At 60 Hz nominal frequency, a 1 percent Total Vector Error (TVE) provides a timing error budget of 26 microseconds. Given there are other sources of errors, the TSTF has established a goal of 1 microsecond or better accuracy to UTC.

According to some work by Zhao et al., angle error as low as ±0.1° can cause a failure, and an angle error of ±0.6° will have an even greater impact.¹

From a study of the Northeast Power Coordinating Council model, an angle error as small as ±0.15° is able to change the first responding PMU.

Okay, We Need Distributed Time
Isn’t That Easy in 2017?

Figure 1: Frequency stability of 8 computer clocks.

Figure 2: Frequency stability of 5 types of oscillators: (O) sapphire crystal; (Z) “zero-beat” servo; (F) frequency servo; (C) circular servo loop; (P) power servo controlled.


The Usual Suspects of Timing

- **Time Standards**
  - UTC (common, includes leap seconds)
  - GMT
  - TAI

- **Oscillators**
  - Hold-over oscillators
  - Physical-layer signaling
  - CPU cycles since last reboot

- **Clock sources** capable of Communicating Time Info
  - Uni-directional broadcast (GPS, eLoran)
  - Bi-directional exchanges
Beyond GPS…

- **NTP (ubiquitous)**
- **PTP (more accurate up to about five routers/switches)**
- **TSN - a group of individuals defining standards in 802.1 for time sensitive networking (e.g. 802.1as is PTP)**
- **Synchronous Ethernet (SyncE); subject to loops**
Basic Idea of a networked time source

Distribution systems (e.g., NTP, GPS) typically do not know about local time zones or daylight saving time. A time server located anywhere in the world can provide synchronization to a client located anywhere else in the world.
An Overview of NTP
It’s All In The Exchanges

NTP Server

Periodically broadcast clock synchronization packets (mode 5)

Synchronization packets (mode 3 and mode 4)

Initiate a request for server/client mode after receiving the first broadcast packet

Interaction of clock synch packets

NTP Client

Obtain a network delay, and enter broadcast client mode

Receive the broadcast packets, and synch the local clock to that of server

PTP Master

timestamps

T1

T2

T3

T4

T1, T2

T3

T1, T2, T3

T4

PTP Slave

T1, T2, T3, T4

timestamps

T1

T2

T3

T4

Known by Slave

T1

T2

T3

T4

Sync

Follow_up

Delay_Req

Delay_Resp

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Strengths & Weaknesses of NTP

Strengths

• Ease of implementation
• Cost
• Robustness

Weaknesses

• Accuracy (Difficult to account for message queuing)
What Happens If We Rely Solely on NTP?
Recommendations & Conclusions

• If you have to deploy now, consider a combination of GPS backed by good hold-over oscillators and/or PTP

• Better yet, if you can wait – trust that something better will soon be available

• Do not consider NTP to be appropriate for distributed, dynamic control of power grid functions
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Questions?

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Extra Viewgraphs