Using Wide-Area Precise Time Distribution to Increase Dependability and Security of Substation Time Synchronization

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Topic introduction

- Critical infrastructures need precise time
- Paradigm shift from relying completely on satellite sources allows packet networks to assist
- Hybrid time distribution gateways bridge the two worlds

Executive Order 13905

Strengthening national resilience through PNT

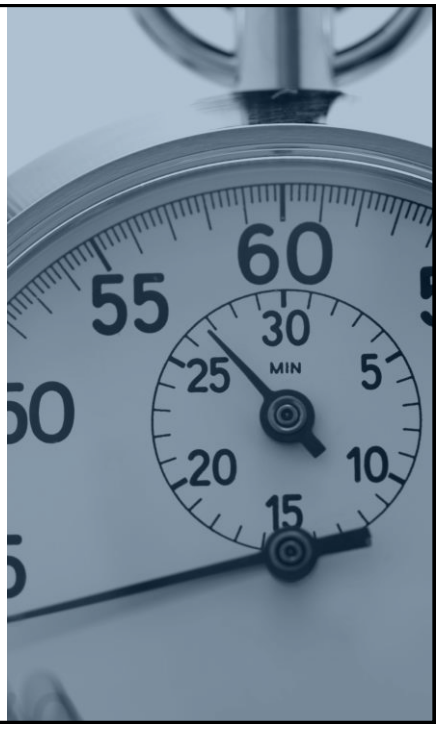
Power grid

Emergency response

Transportation

Precise time usage in power system applications

- Synchrophasor measurements
- Sampled measured values
- Line current differential protection
- Traveling-wave fault locating
- Time-domain protective relaying



PTP for power industry

- Focus – PTP in LAN
- IEEE 1588 Power Profiles
  - IEEE/IEC 61850-9-3:2016 Base Power Profile
  - IEEE C37.238-2017 Extended Power profile
  - IEEE 1588-2008 Annex F
    (default profile for transport of PTP over IEEE 802.3/Ethernet)

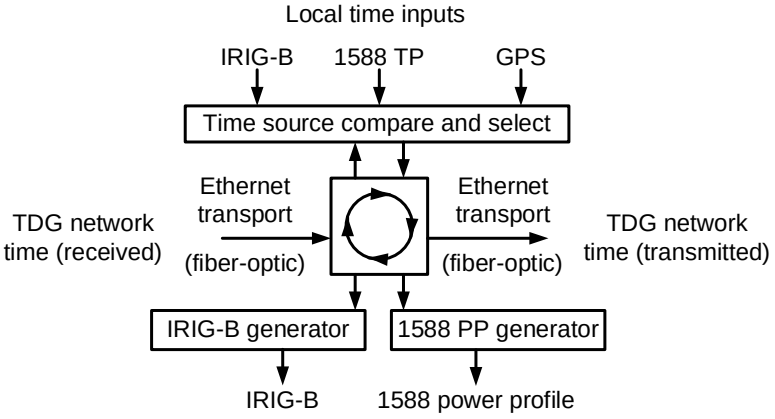
Getting PTP to LAN

Time distribution gateways (TDGs) can

- Source precise time from WAN (1588 TP)
- Perform a conversion to LAN (1588 PP)

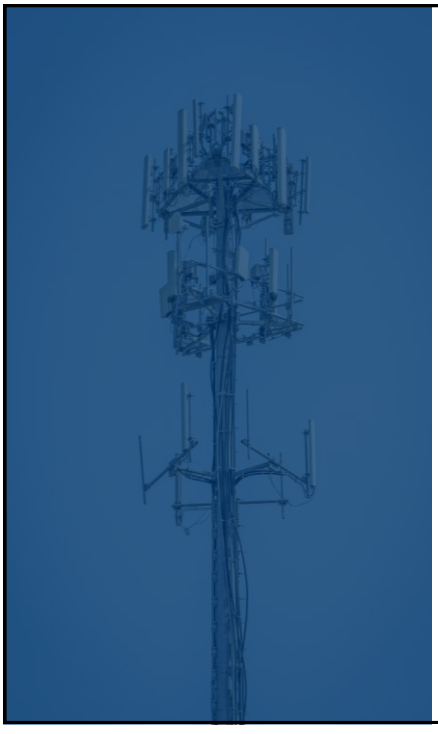
Time distribution gateways

- Input time
  - Satellite-based GPS or IRIG-B
  - PSN-based via 1588 TP
- Output time
  - IRIG-B
  - PTP PP



How do TDGs communicate and distribute time across a WAN?

- Ethernet pseudowires across WAN
  - Mimic direct fiber-optic TDG connectivity
  - Are available from MPLS and Carrier Ethernet PSNs
- TDGs build virtual synchronous network (VSN)
  - Take time from satellite and PSN sources
  - Agree on system time
  - Extend LAN connectivity and distribute time to IEDs



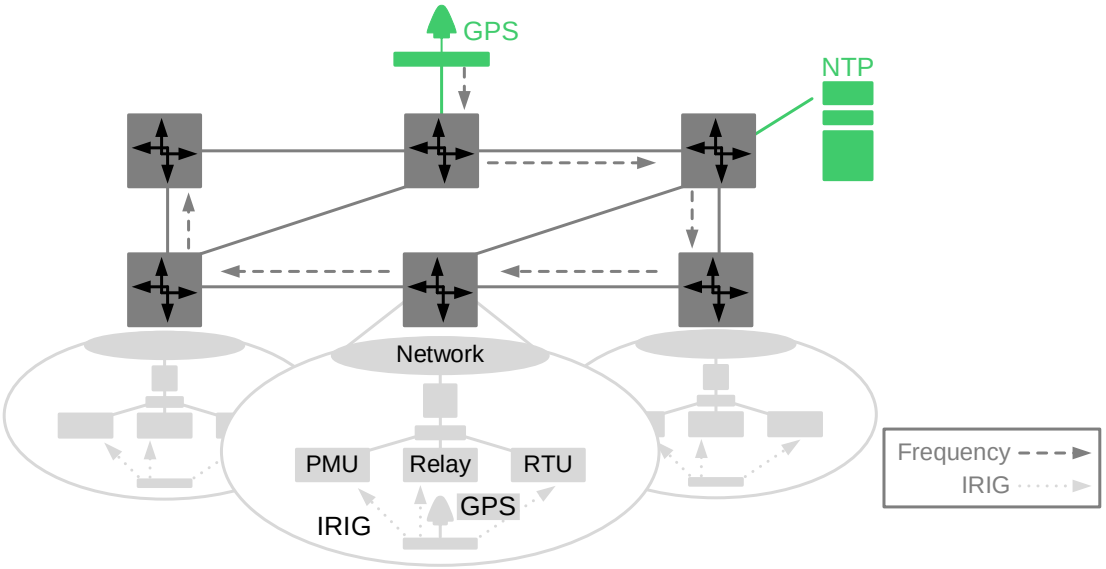
Timing designs

Central vs. distributed

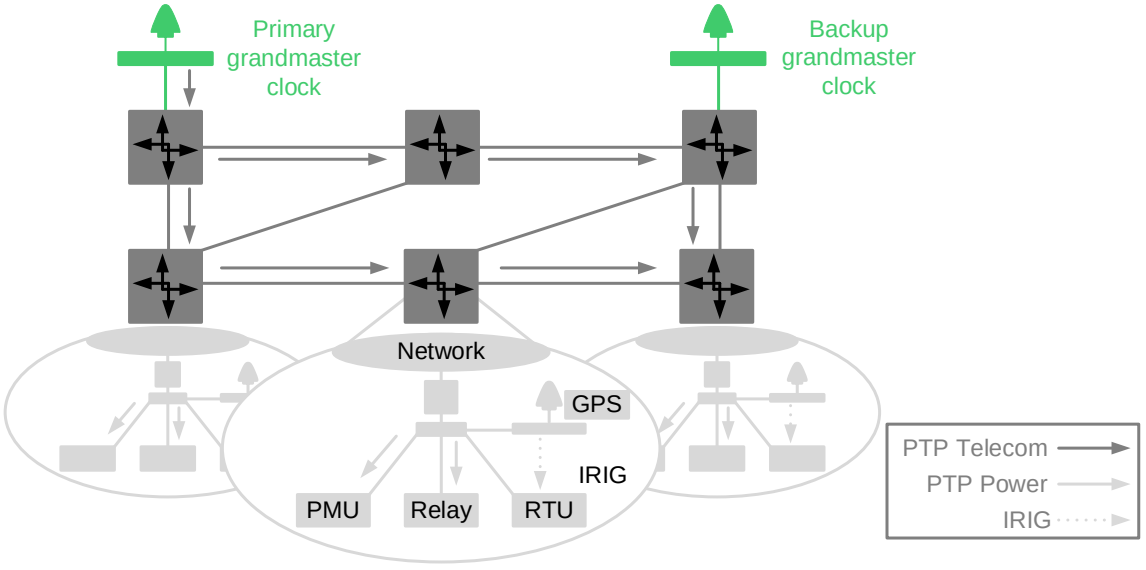
Design change considerations

- Network timing design
- Grid timing reliability
- Cyber asset protection

Decentralized network timing design



Centralized network timing design

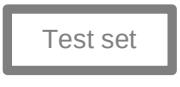


Concept validation

Equipment

Grandmaster clock supporting 1588 telecom profile

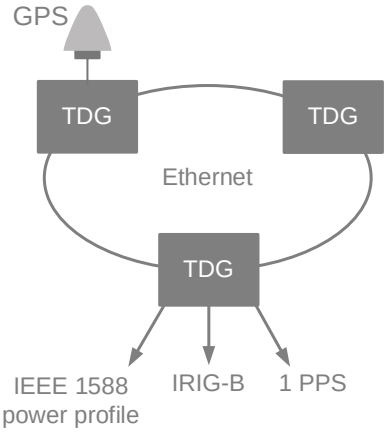
Telecom equipment; three sites supporting 1588 TP



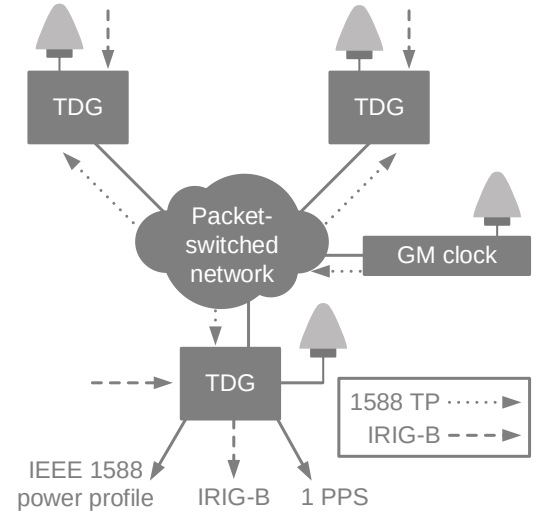
Test set measuring and providing accuracy of 1588 PP

Three TDGs and three substation clocks

Concept validation network models

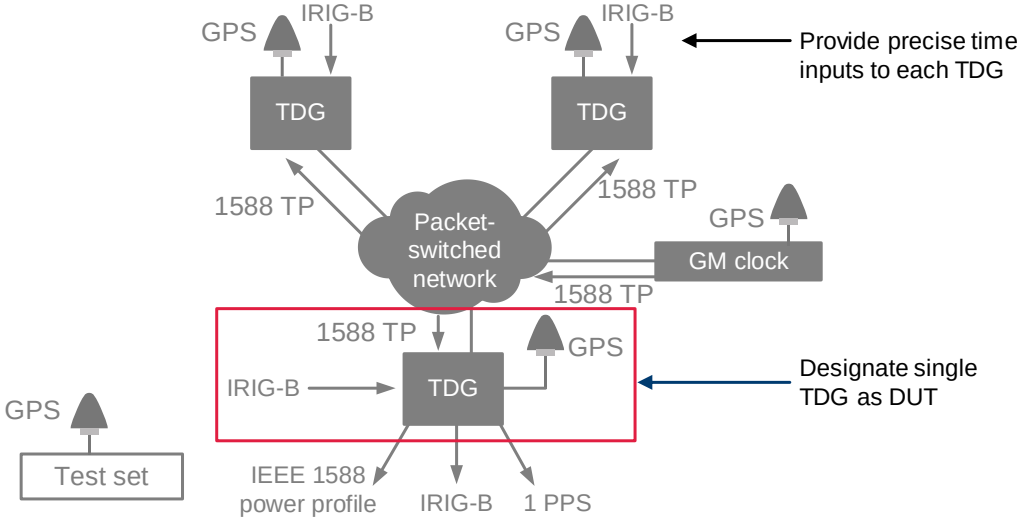


Model A – Direct fiber connected



Model B – Transport connected

Topology



Scenarios

Four validation scenarios at TDG node

- Test 1 – remove GPS
- Test 2 – remove IRIG-B
- Test 3 – remove 1588 TP
- Test 4 – remove GPS, IRIG-B

For each scenario

- Remove time source(s)
- Collect performance data
- Evaluate time quality output by TDG
- Recover time sources

Pass criteria

- VSN stays up and running even when one or more inputs are lost
- Precise time output is always maintained
- Time output error and phase offset are within advertised clock accuracy limits

Time input observations

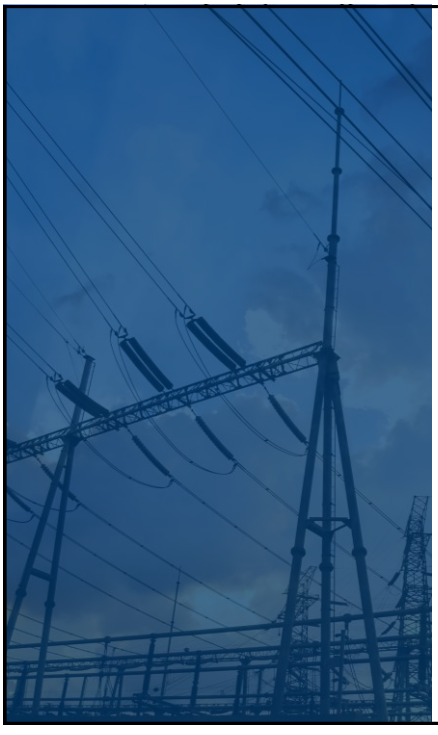
- TDG correctly functioned using any combination of highly accurate sources of time: GPS, IRIG-B, and 1588 TP
- Across all active sources, incoming time was weighted (based on time quality) and averaged
- Loss of any single time source input when others were available had no observable impact on TDG network operations

Time output results

Validation results	Test 1 GPS loss	Test 2 IRIG-B loss	Test 3 1588 TP loss	Test 4 GPS and IRIG-B loss
Valid sources	IRIG-B and 1588 TP	GPS and 1588 TP	GPS and IRIG-B	1588 TP only
Observations	1588 PP frames received throughout; VSN stays running			
Advertised clock class	Synchronized to PRC			
Advertised clock accuracy	250 ns	250 ns	250 ns	250 ns
Measured time error	163 ns	166 ns	28 ns	240 ns
Measured phase offset	–157 ns	–171 ns	–69 ns	–221 ns

Conclusions

- TDG timing solutions increase reliability and availability of precise time for power utility substation applications
- TDG proves that a hybrid approach of satellite- and PSN-based time sources can help mitigate disruption and protect critical infrastructure



Questions?