GPS Timing Challenges and Robustness Needs for Critical Infrastructures: 
*Examples from Telecom, Broadcast and Power Delivery Industries*

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Overview

• Who we are
• What is our PNT problem?
• Potential remedies
• What we’re doing about it
We represent your PNT customers

• Net Insight provides time transfer solutions as part of network services to the telecom and broadcast industries.

• NASPI is working to advance the use of synchrophasor (time-synched) technology to improve power system reliability and economics.
  – Many North American power sector participants
  – International membership
  – Partnerships with federal agencies, national labs, research organizations
Here’s what we know about PNT:

• There are many ways for existing PNT systems to fail, whether from error, accident, or attack.
  – We’ll show you some of those failures and consequences from our PNT users’ perspective.
• We need PNT to fail less – but that’s beyond our scope and pay grade....
• Users need to prevent and mitigate against failure -- whatever the cause – using better prevention, detection, redundancy and resiliency measures.
How telecom and broadcast use PNT

• Both telecom and broadcast are critical infrastructures and must be robust and resilient

• Telecom needs stable frequency
  – Modern telecom & mobile networks are phase-aligned
  – GPS receivers cheaper than cesium clocks

• Broadcast networks need stable frequency
  – Broadcast transmitters need UTC
  – GPS receivers allow SFN transmission
Typical GPS clock used for telecom and broadcast

- GPS L1 C/A code phase signal, UTC timescale
  - Sufficient for most uses
  - Cheap OEM module for time
- Basic time interface
  - 10 MHz, PPS, NMEA
- Additional output signals feasible
  - IRIG-B, NTP, PTP, 2.048 MHz, 1.544 MHz
- Receiver monitoring is needed to identify potential problems and alert user
Consequences of recent GPS problems for European telecom & broadcast

• 26 January 2016 GPS event – SVN 23 removed from constellation, 15 of 31 satellites had 13.7 us UTC time-error; GPS clocks fluctuated wildly, shifting between satellites
  – Telecom PTP long-term test failed in Berlin
  – Broadcasters had DVB-T and DAB SFN failure (noted in BBC press release)

• 1024 week wrap-around affected older GPS receiver
  – stopped a financial market

• PRN31/SVN52 launch – affected some GPS receivers
• PRN32 launch – killed a national telecom network
Other experiences

• Leap seconds
  – Have affected several networks
  – But each new leap second has less impact

• GPS jammers
  – Have closed ports and airports
  – Used for crimes such as stealing cars

• GPS receiver installation problems including snow, ice, water, steam, lightning, other transmitters and Christmas tree
  – Have caused time transmittal problems
PNT from the electric grid perspective

• Power systems today use mostly GPS for locational purposes, not for timing.
  – Also heavy telecom and IT network dependence, which rely on timing delivery services

• Synchrophasor technology does high-speed grid monitoring, time-synchronized to UTC with microsecond accuracy. When networks and timing become more reliable, synchrophasor technology can become a mission-critical tool.
  – GPS is the dominant timing delivery service today for Phasor Measurement Units (PMUs)
  – Still telecom and IT network dependence...
Some of the ways timing goes bad from the grid user’s perspective

• On-site
  – GPS receiver – poor quality, software bugs, no firmware updates, bad location, local jamming or spoofing, lost wire to the PMU, no correction for PNT broadcast problems
  – PMU – poor interoperability with GPS receiver, slow firmware patches, lost wire to GPS receiver, sloppy program for time-handling, no detection of timing problems, no back-up time source

• In Phasor Data Concentrator and applications – inadequate detection of timing anomalies or gaps and computational errors resulting from those problems
What happens to synchrophasor measurements if GPS goes bad?

• If there is an error or spoof of the time signal to a phasor measurement unit (PMU), that error will cause false calculations of phase angle and mis-alignment of measured grid conditions relative to other PMUs.

• In the case of the leap second:
  – Where the GPS clocks skipped the second or were early/late, PMU measurements were too early or too late, causing PDCs to ignore the PMU measurements
  – Where there were duplicate time stamps, there were “duplicate” PMU measurements
  – Phase angle error depends on accurate time information; bad time stamps mean erroneous phase angle calculation
Calculating phase angle with time error

For 17 seconds, it appears that the phase has a 36 degree error (at 59.9Hz)

Note that there are no reports for the second immediately following the leap second

And there are two sets of reports for the second between 17 and 18 seconds after.

Random changes in angular difference after the leap second

Random changes in angular differences observed in some PMUs after 23:29 in the POSOCO (India) control center

Different PMUs handled (mis-handled) the leap second differently

Sources:
POSOCO, P.K. Agarwal,
“Encounter with the Leap Second,” NASPI Work Group,
March 23, 2016
Power system punch lines

• Timing errors from the time source can cause incorrect synchrophasor data
  – Such errors can create false analytical conclusions and drive undesirable and possibly dangerous automated grid operations.

• The power sector needs to protect future grid operations with better timing tools and practices to improve robustness and resilience
  – We need to assume that PNT could be unreliable at both source and the receiving points
  – We need to start implementing measures to assure accurate, reliable time stamps against multiple failure modes
Remedies at the PNT level

• Improved signal robustness checks
• Multi-frequency – L1 C/A, L2C, L5 (but multi-frequency receivers are expensive)
• Multi-system – GPS, GLONASS, GALILEO, eLoran – a few GPS + GLONASS receivers exist (mainly because Russian law prohibits dependence on GPS only)
• Multiple receivers – only addresses hardware failure
• Jamming and spoofing detection and/or prevention
• GPS-independent networks
More remedies -- GPS-independent networks

- Telecom network is capable of Time Transfer -- avoids dependence on satellites and transmitter sites and requirement for large receiver network installation and maintenance
- Network-distributed time can receive accurate time from multiple sources (GPS, NTP, CDMA, PTP), some IRIG-B
- Distributed clock networks, some IEEE 1588
- Holdover clocks for short-term back-up
What we’re doing about it – NASPI Time Synchronization Task Force

Scope – Time synchronization awareness and problem-solving for electric sector, with synchrophasor focus

• Document problems of current PNT solutions
• Identify specific, near-term solutions and mitigations that can address multiple failure causes (redundant timing sources, better installation and maintenance, detection of bad or anomalous time signals, specs for good-quality equipment, etc.)
• Develop and share how-to information for these solutions
• Recommendations for longer-term research needs (timing problem detection, equipment interoperability, standards updates, etc.) within grid sector and beyond
NASPI Time Synchronization Task Force (2)

• Participants
  – Power system representatives (BPA, Dominion, NERC)
  – National labs and research orgs (NIST, PNNL, ORNL, SWRI, EPRI, U.S. DOE)
  – Private sector experts (MITRE, Net Insight)
  – More volunteers welcome!

• Timing
  – Start in May 2016
  – Major product by March 2017
  – Follow-up to be determined
Big picture NASPI TSTF goals

• Find ways for the power sector to improve timing delivery reliability and resilience for synchrophasor technology and grid operations
  – Coordinate, focus and share work and results within the power sector
  – Develop and deliver materials for non-expert use

• Leverage timing delivery expertise and resources available beyond the power sector
  – Help you understand our needs
  – Gain access to better equipment, software and practices – short- and long-term
Thank you

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