WORKSHOP
ON
SYNCHRONIZATION
AND
TIMING SYSTEMS

Virtual Webinar Series

Session 2

Timing in Finance, Electric Power and Broadcast

May 13, 2020

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atis

Timing in Finance, Electric Power and Broadcast Overview

Pat Diamond
Principal
Diamond Consulting

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May 13, 2020

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Chair: Pat Diamond - Principal, Diamond Consulting

Vice Chair: Tommy Cook - CEO, Calnex Solutions

Speakers: Victor Yodaiken - CEO, FSMLabs

Sarath Madakasira - Principal Software Engineer, Microsoft

Keith Mange - Principal Software Engineer, Microsoft

Tommy Cook - CEO, Calnex Solutions

Jeff Dagle - Chief Electrical Engineer, Pacific Northwest National Laboratory

Gerardo Trevino - Technical Leader, Electric Power Research Institute

Jaime Jaramillo - Senior Director Americas, ADVA Optical – OSA

Steve Guendert - IBM Z Timing Hardware Systems Architect, IBM

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May 13, 2020

- The vWSTS webinar series is being held in place of the annual face-to-face WSTS.
- Today's webinar is the second in a series of three:
  - **May 6** – 5G and Smart Cities
  - **May 13** – Timing in Finance, Electric Power and Broadcast
  - **May 20** – Timing Security, Resilience and GNSS Issues
- Thank you to today's speakers, as well as Calnex Solutions for sponsoring this webinar.
- Attendees will receive an email with the slides and a link to the recording shortly following today's broadcast.
- There are two Q&A sessions during this webinar.
  - Submit questions at any time using the question tab on the control panel located on the right side of your screen.
- Follow ATIS on Twitter @atisupdates

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Timing in the Face of COVID-19: A Look at Financial Market Impacts

Victor Yodaiken
CEO
FSMLabs

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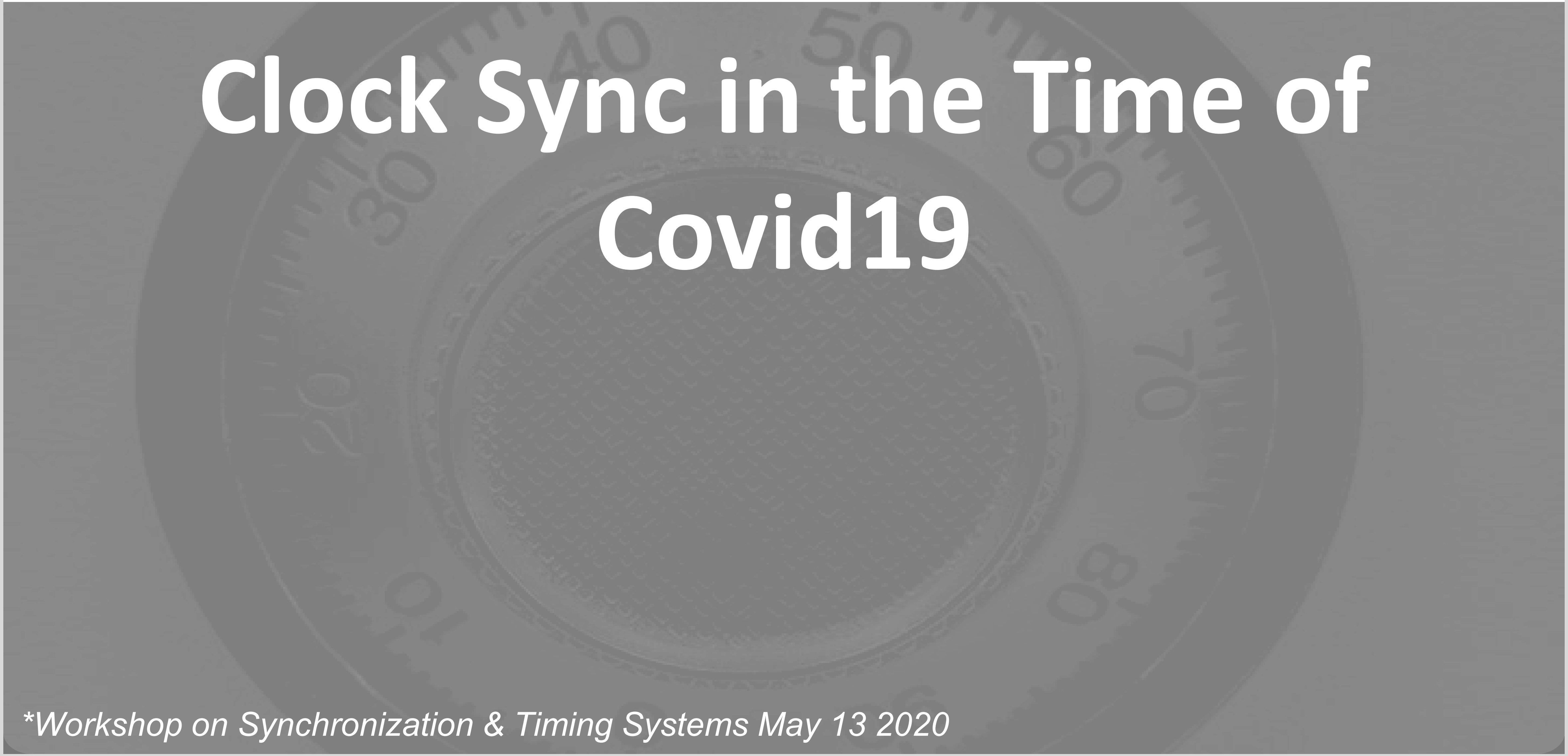


Clock Sync in the Time of Covid19

**Workshop on Synchronization & Timing Systems May 13 2020*

Time for isolation

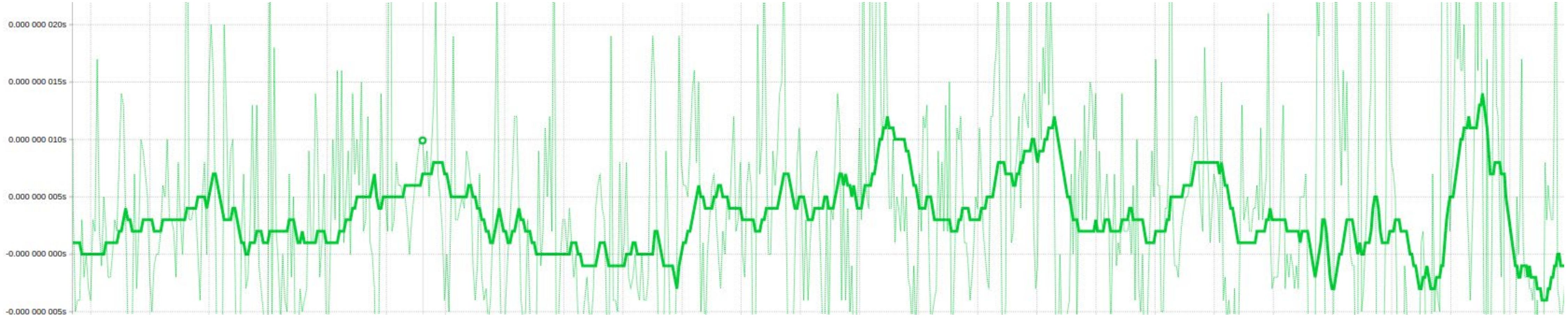
- Clock Sync for a home office reveals a lot about challenges in the data center
- Low skilled workforce (or over-committed)
- Commodity hardware
- Networking issues
- Monitoring and alerts

Issues

- Many of the issues covered here are important in data centers too.
- There is a growing regulatory emphasis on desktop “business clocks”.
- Exposition focuses on tools and analytical graphs that come with TimeKeeper but are general issues.

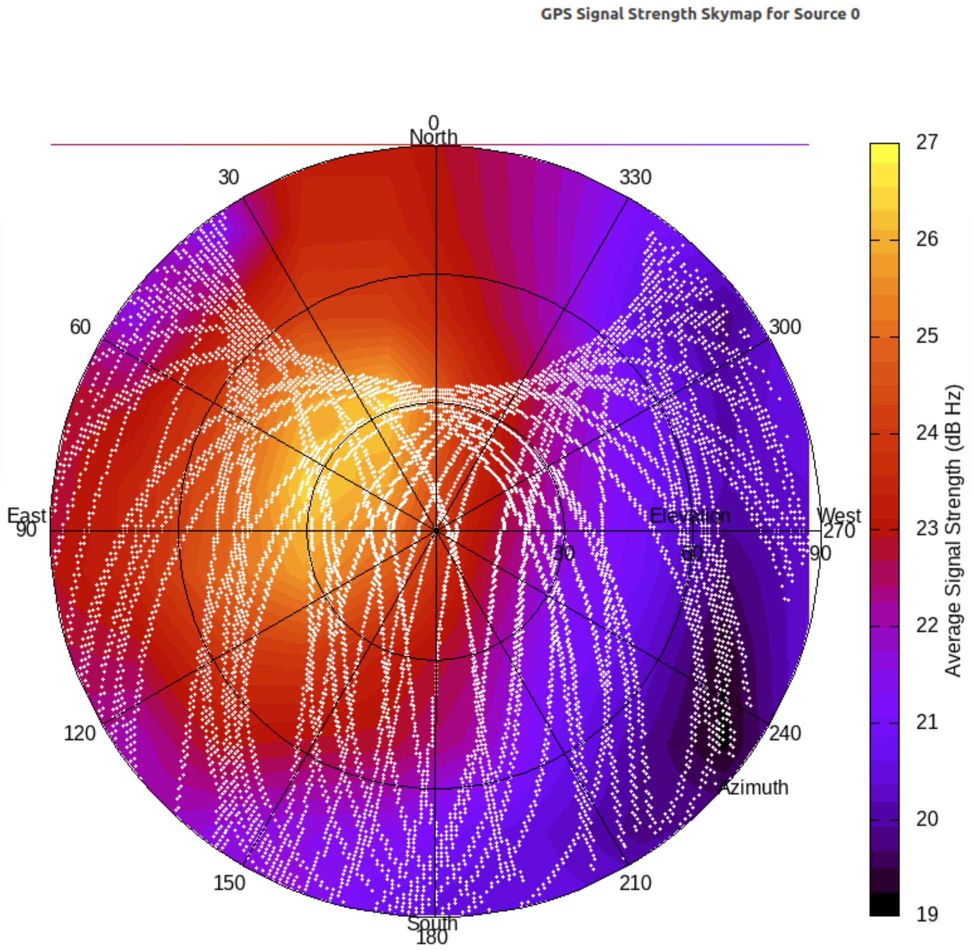
Cobbled together GM in a desktop

Tracking GPS to within a few tens of nanoseconds (Y axis scale 5ns grid)



Commodity GPS/OCXO module and a lot of software control algorithms to make up for device oscillator, intermittent fans, PCI-delays, interpolation, etc.

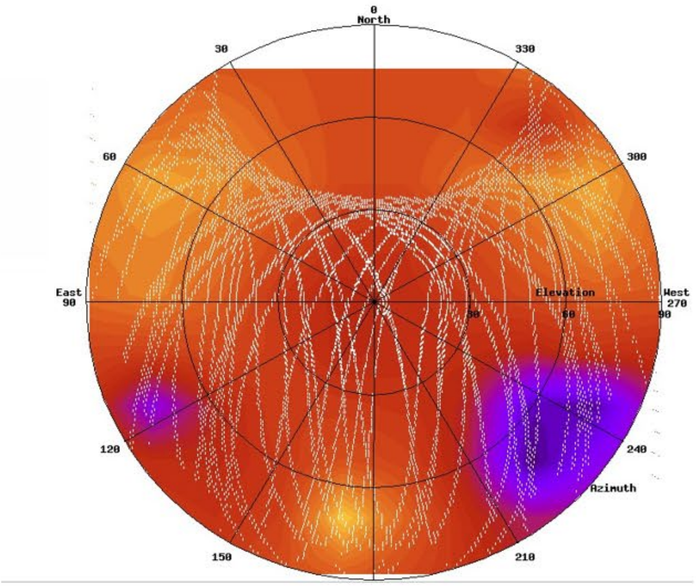
The antenna and the view



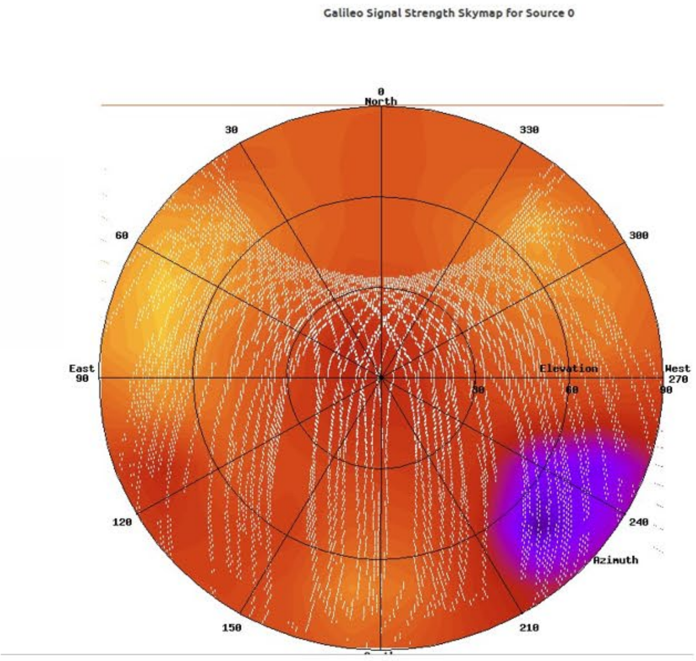
TimeKeeper "skymap" shows roof to the left (dark)

In a data center – there may be multiple constellations

Sky view for different constellations should not differ radically. If one changes and the others don't – problem with that source.

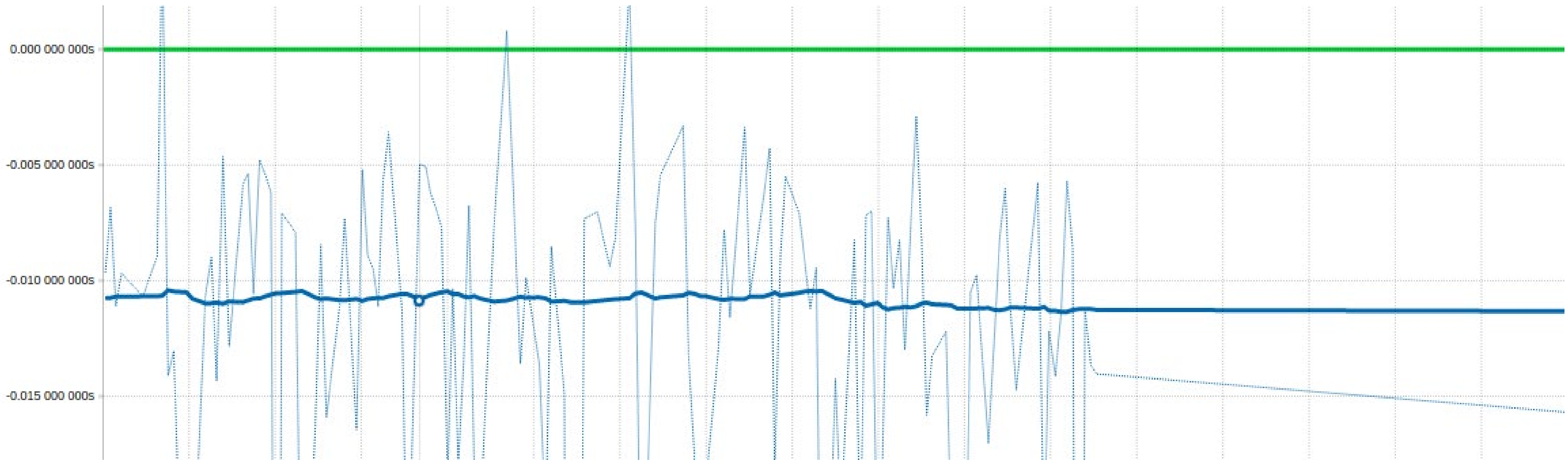


GPS



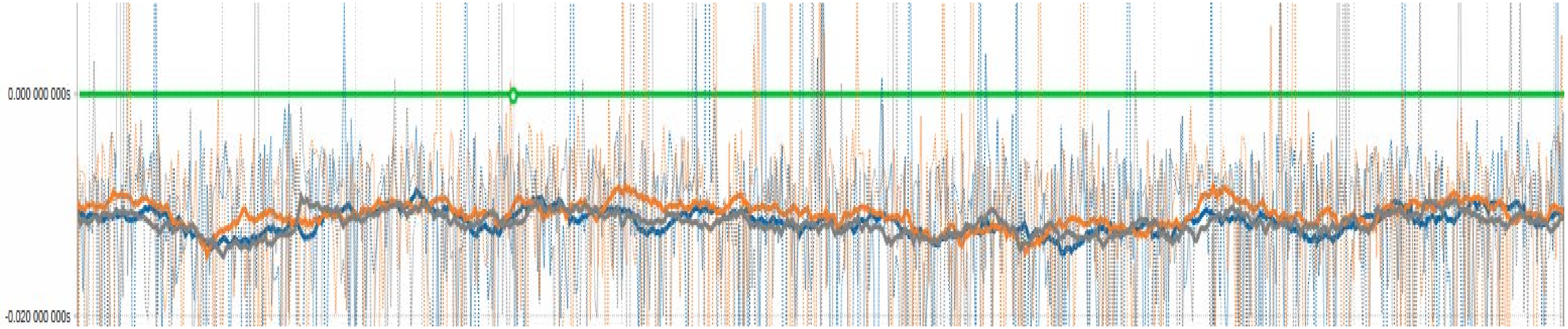
Galileo

GPS versus internet NTP (thanks U. of H)



We can track the Internet NTP source pretty well, but it is 10 milliseconds off. A single clock source is impossible to validate from the client. On the other hand, this is external validation of gross time and frequency.

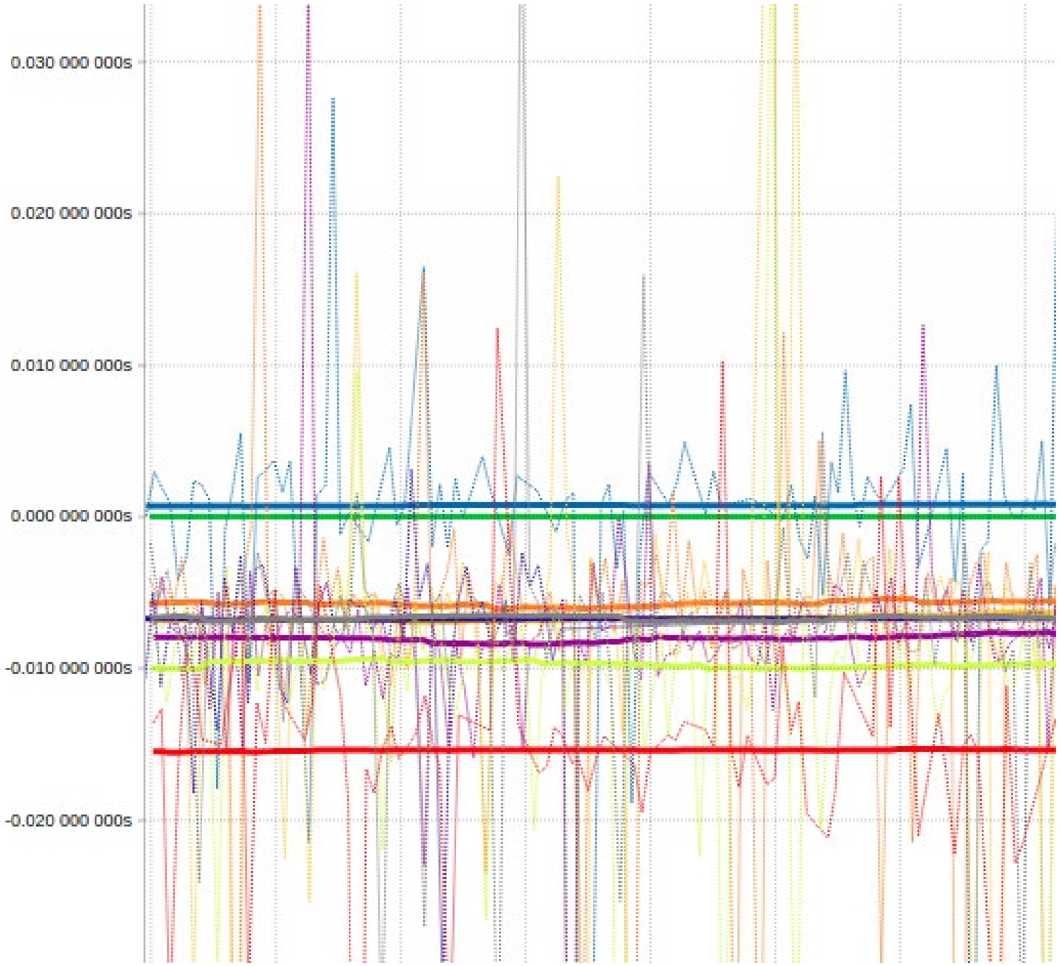
Multi-Source



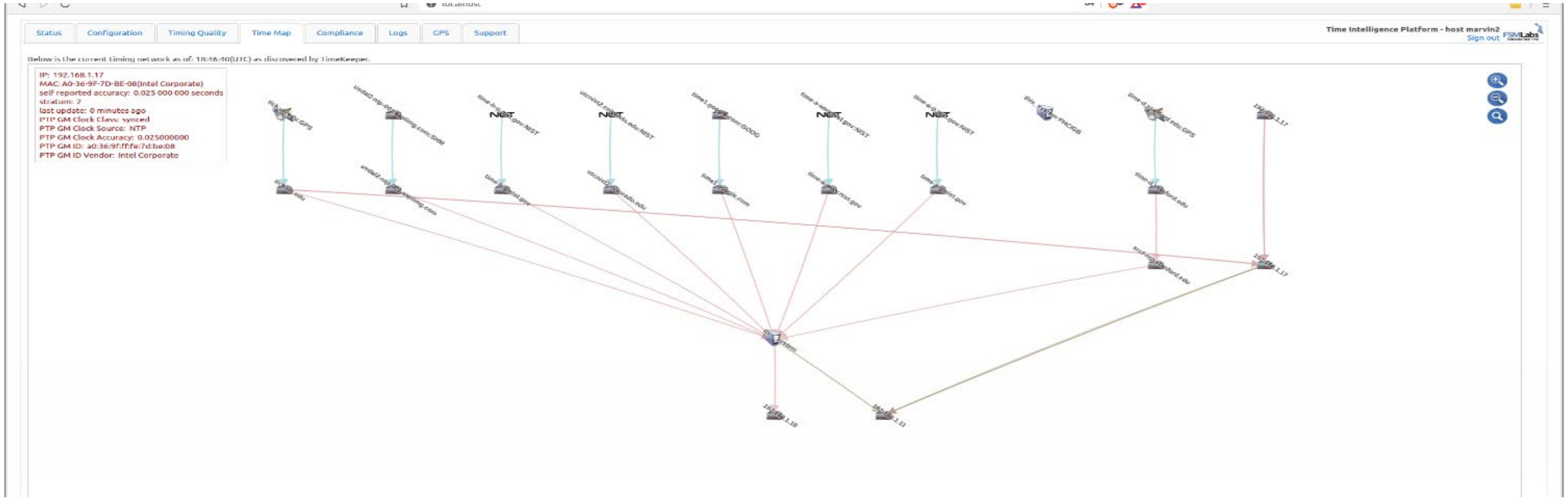
Tracking multiple NTP sources shows they all agree and all have the similar offset. This is probably due to Comcast. But it shows how time provides valuable network connectivity data and limitations of aggregation (you need a smart IT staff, or in this case one with access to smart advice, to distinguish source quality).

Redundancy

Even in this case, once U of. H is shown to be pretty reliable (over long measured intervals), its offset can be corrected to provide some resiliency if GPS fails or is spoofed (I don't trust my neighbors, many of whom are technically sophisticated). See the blue line which has been corrected to align with the GPS green line.



Another view of the network



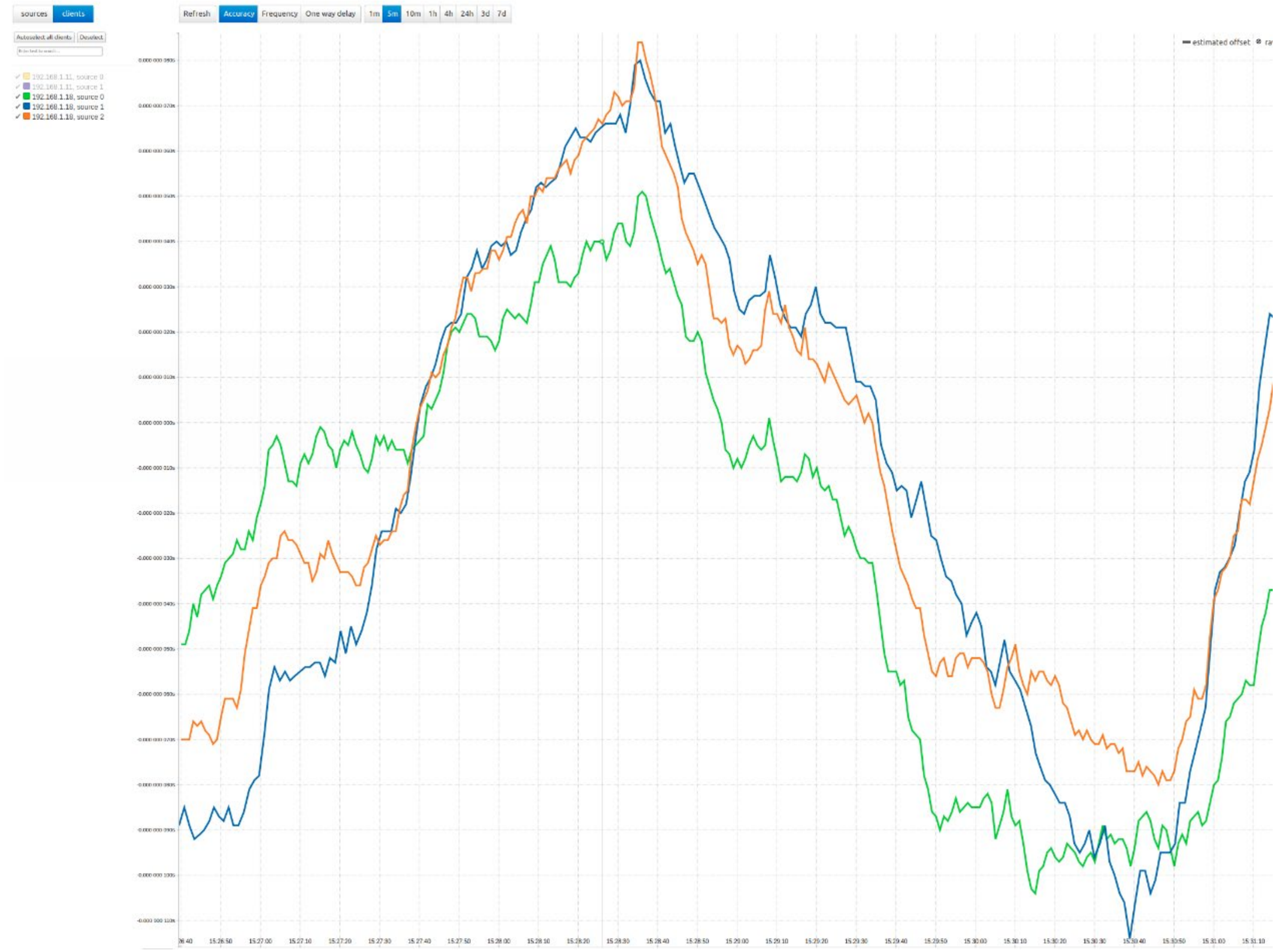
This shows my selection of clock sources and their sources – when GPS fails and we're falling back on NTP.

A desktop client

Current Local Source Snapshot Details	
Source	**Estimated offset**
(1) PTP: Domain 0 (unicast)	0.000000824
(2) PTP: Domain 0 (unicast)	0.000000802
(0) NTP: 192.168.1.17	0.000000611

Both PTP and NTP (the incorrect folklore theory NTP is limited to milliseconds is not consistent with the data.)

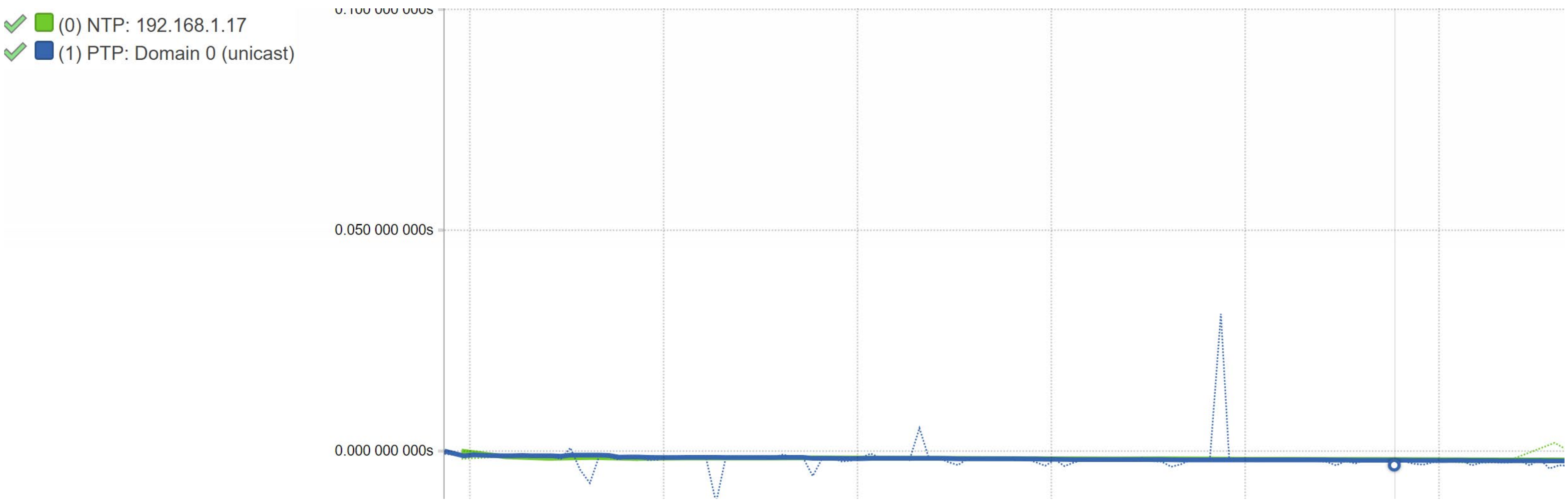
Same desktop client tracked by the GM



Both PTP and NTP. The graph looks terrible but the distance from peak to valley is under 200 nanoseconds.

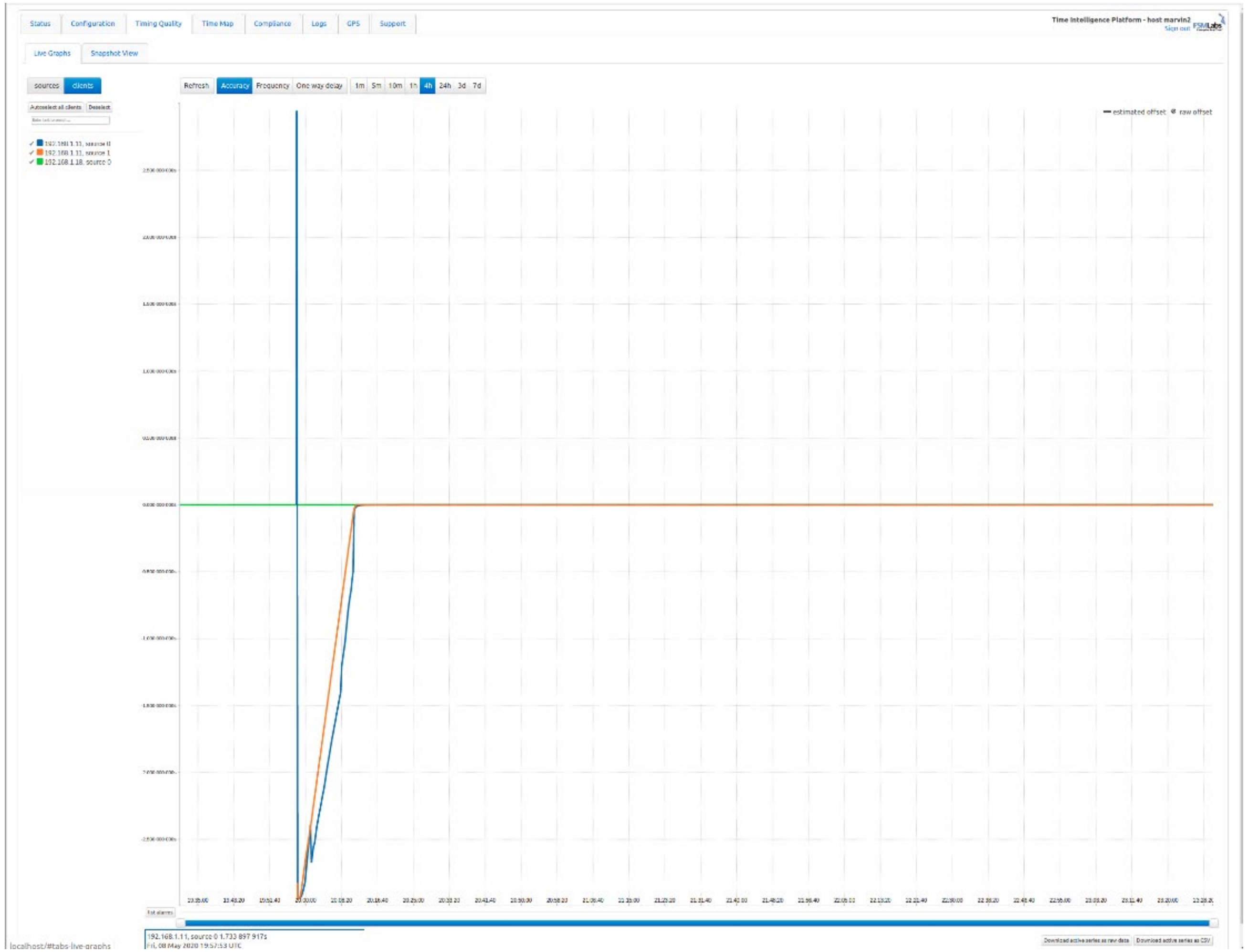
The numbers were improved from previous slide by changing the network configuration.

On the back porch



Timekeeper on a notebook computer over wireless (well within the 50 millisecond level regulations are starting to require for "business clocks" on the edge (PTP and NTP feeds validate each other).

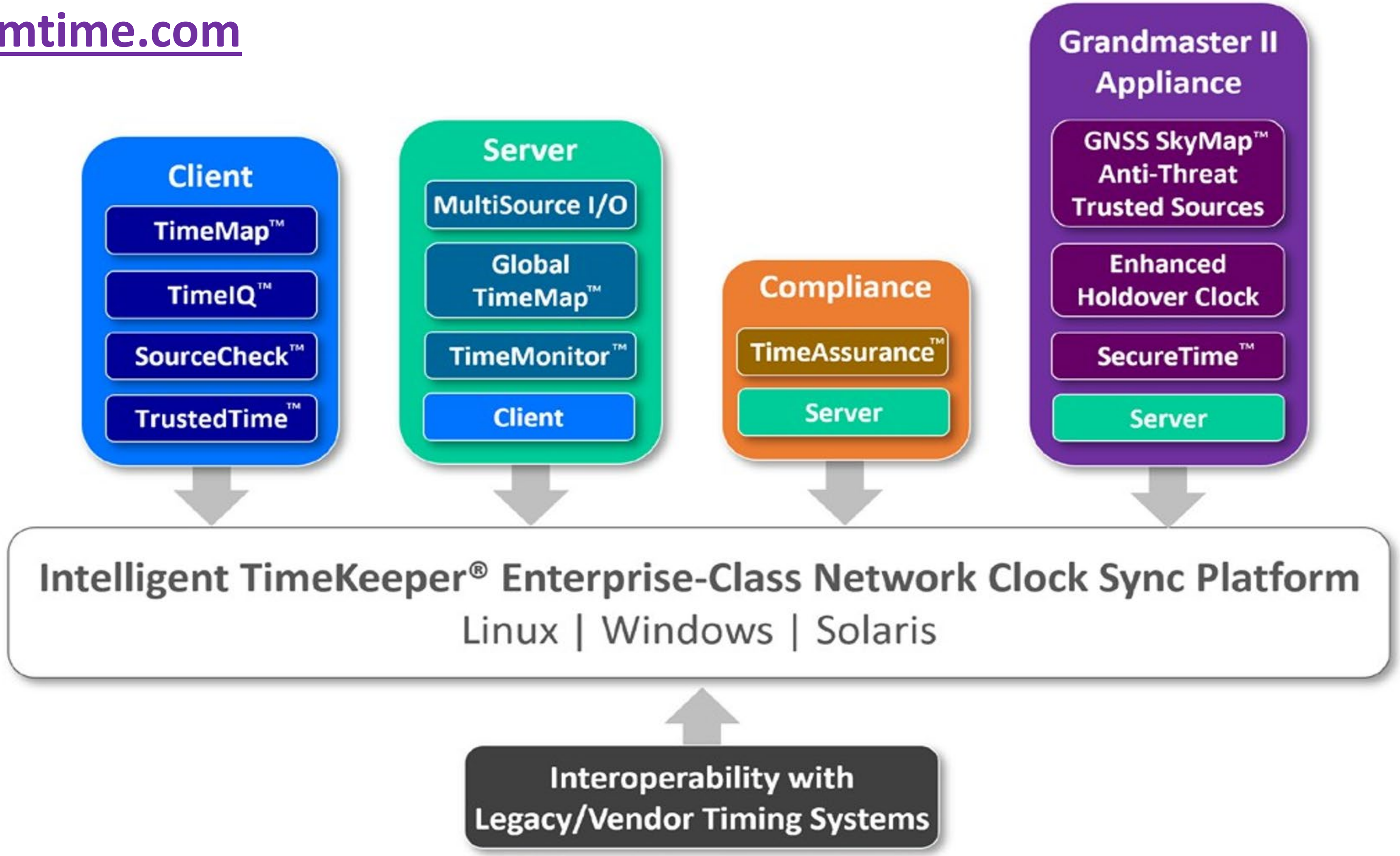
Notebook has some of same issues as VM



Closing the lid on the not book suspends the clock. The rapid slewing preserves time ordering but returns the system to correct time (the green line is the primary clock on the client)

Contact FSMLabs/FSMTime

sales@fsmtime.com



WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Recent Improvements to High Accuracy Timekeeping in Microsoft Windows OS

Sarath Madakasira
Principal Software Engineer
Microsoft

Keith Mange
Principal Software Engineering Lead
Microsoft

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Microsoft

Recent Improvements to High-Accuracy Timekeeping in Microsoft Windows OS

vWSTS Conference - May 2020

Sarath Madakasira, Principal Software Engineer, Microsoft Corp.
Keith Mange, Principal Software Engineering Lead, Microsoft Corp.

Agenda

Timekeeping in Windows Server 2019

New PTP Features and Timekeeping improvements in Windows Server Next

PTP in Data Center Environment

Time sync test results in Server Next

Timestamping API, Windows Insider Program etc.

Timekeeping in Windows Server 2019

- Software Timestamping support in NTP Client/Server
- UTC-Compliant Leap Second support in Windows and NTP Client/Server.
  - https://doi.org/10.33012/2019.16762
- Framework for hardware timestamping of network packets
- Essential PTP Client(Slave) introduced
  - PTP over UDP/IPv4, Unicast/Hybrid modes using end-to-end Path Delays
  - Software Timestamping enabled and performs as well as NTP under similar conditions
  - https://github.com/microsoft/W32Time/tree/master/Precision%20Time%20Protocol
- Further reading:
  - https://techcommunity.microsoft.com/t5/networking-blog/evolution-of-timekeeping-in-windows/ba-p/778020

New PTP Features in Windows Server Next

- Hardware Timestamping integration with PTP Client
  - Currently restricted to 1 NIC on a machine
- Additional PTP Client features and modes, thanks in part to customer feedback.
  - Full-Multicast Mode (currently restricted to 1 NIC on a machine)
  - “Allow Any PTP Master” feature
    - Combined with multicast mode, enables plug-and-play PTP
  - PTP Leap Second Support
  - End-to-end residence time correction
  - Configurable PTP Domain Number

Timekeeping Improvements in Server Next

- Faster time convergence and improved clock stability when correcting larger time offsets
- Refining and adding to the dedicated W32time and PTP event logging for troubleshooting and record keeping.

PTP Data Center Deployment – a proof of concept

We deployed Windows PTP client in a data center environment as a proof of concept.

Learnings:

- Configuring existing network switches as boundary clocks allows scaling accurate time dissemination in a controlled environment – as was intended in the PTP specification.
- PTP + Software Timestamping in a v-cluster of about 40 machines in a large data center helped us realize time accuracies of ~50 microseconds across the cluster.

PTP Data Center Deployment – a proof of concept

Related info:

- Many models of network switches support some PTP modes, but not necessarily all modes.
  - Identifying the required modes upfront can help speed up the deployment.
- Network switches seem to have sufficiently accurate timekeeping to help us realize sub-50 microsecond accuracy across 3 switch hops.

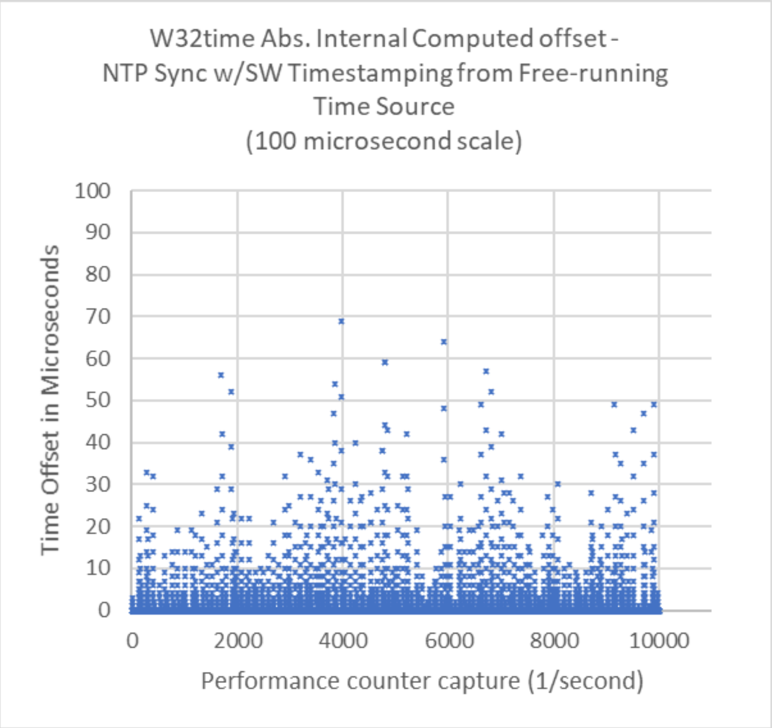
Accuracy Testing Topology

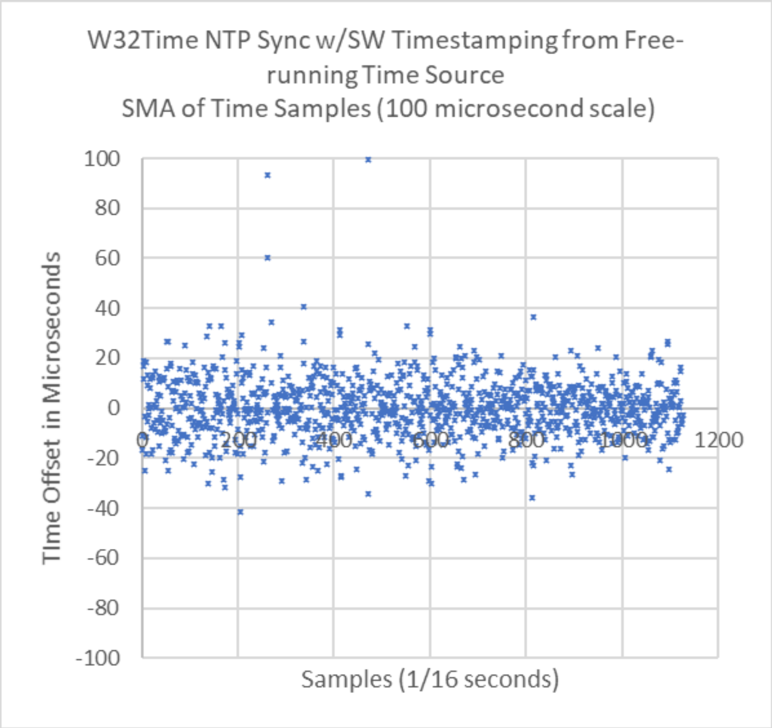
Test topology consists two generic server blades connected via a generic switch (all a few years vintage).

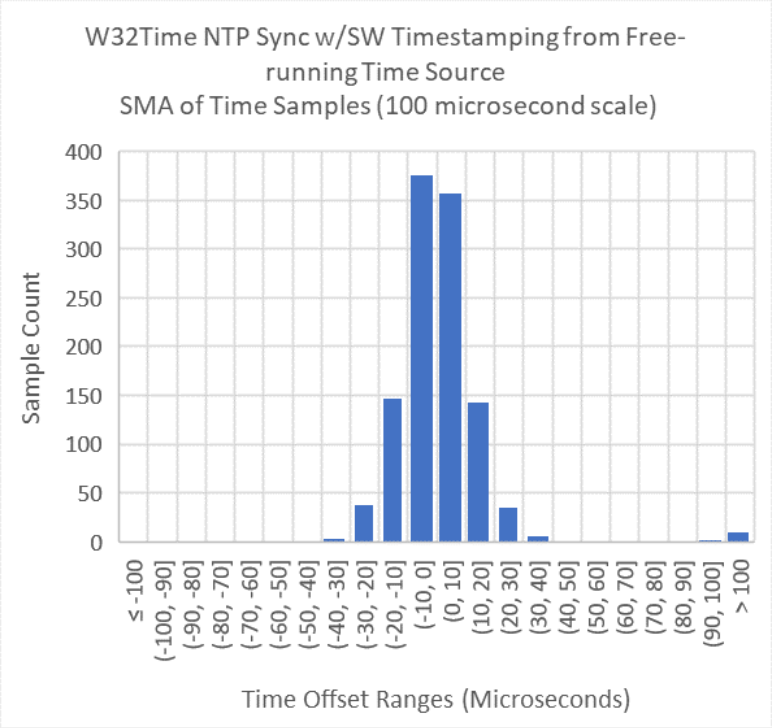
We are running either an NTP or a PTP server on one of the machines and transferring the time information to an NTP or PTP Client on the other machine.

- The time source is the free running system clock on the server.
- Only new hardware components here are NICs that support Hardware Packet Timestamping supplied by Independent Hardware Vendors (IHVs).
- Relevant software includes Windows Server Next and NIC drivers supplied by IHVs.
- For testing NTP, we enabled Software Timestamping and used our Server Next NTP Server and Client (Not significantly different from the released versions).
- For testing PTP, we enabled Hardware Timestamping and used a private PTP Master along with our Server Next PTP Client.

NTP +SW Timestamping Test Results - Baseline





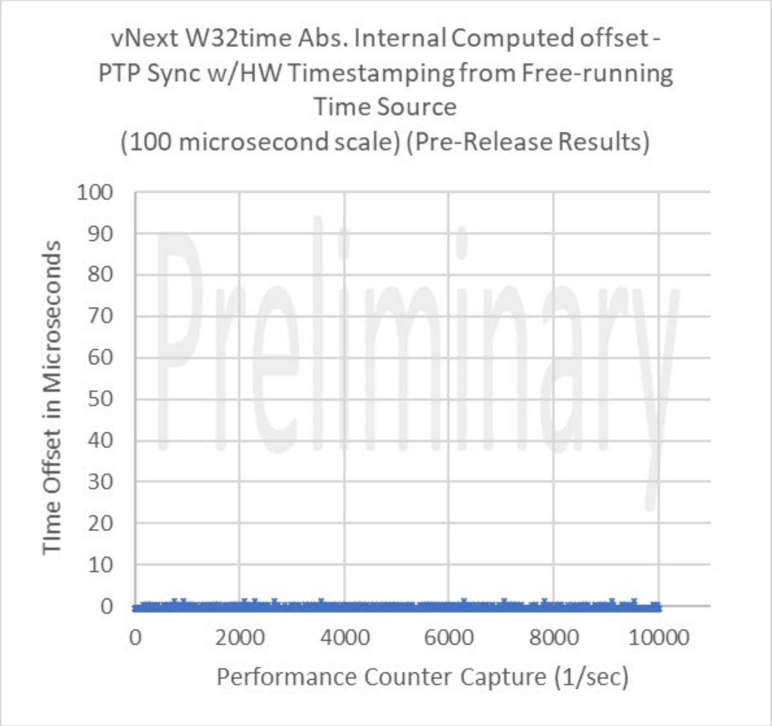


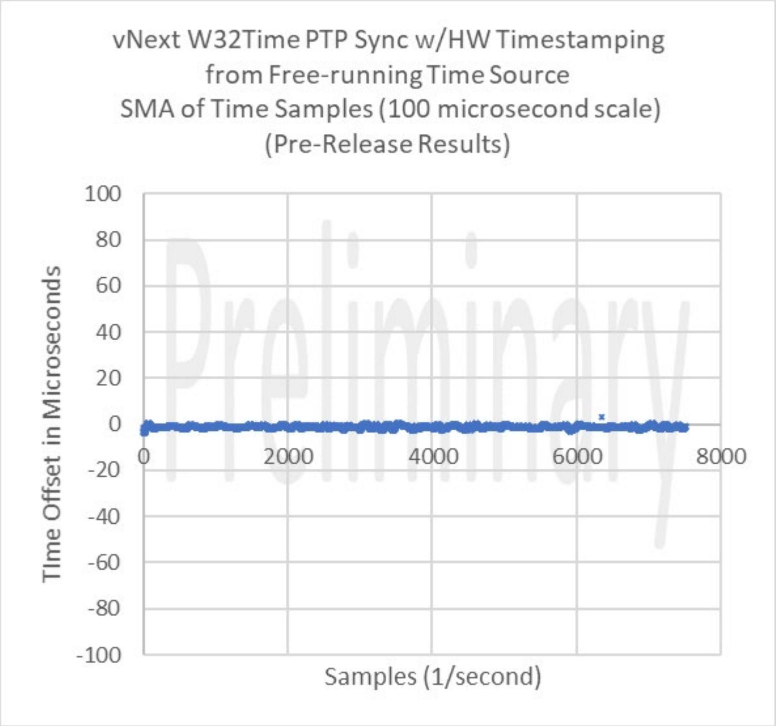
"Computed Time Offset" Performance Counter capture

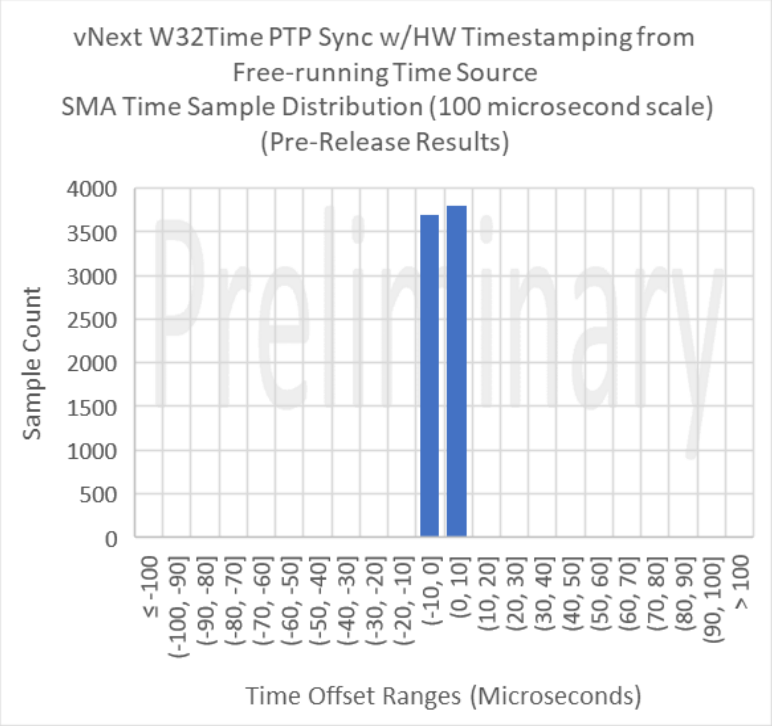
NTP Sample Offset

NTP Sample Offset Distribution

PTP + HW Timestamping Test Results – Best Observed Scenario





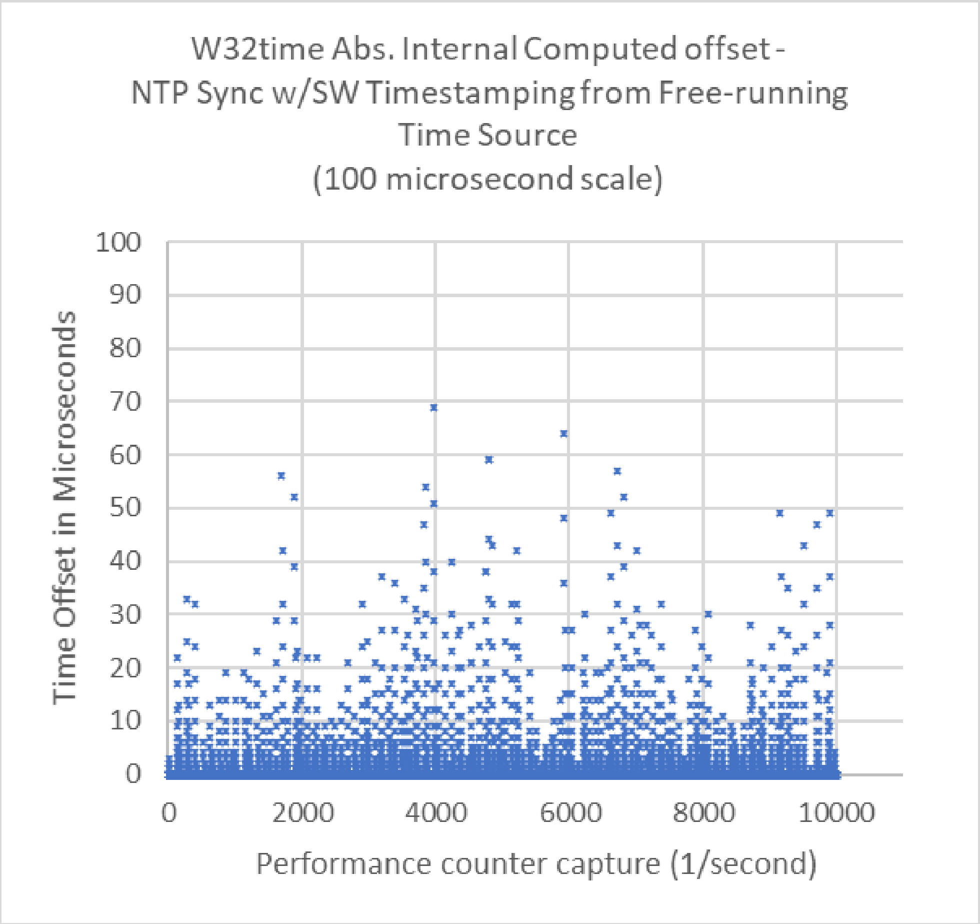


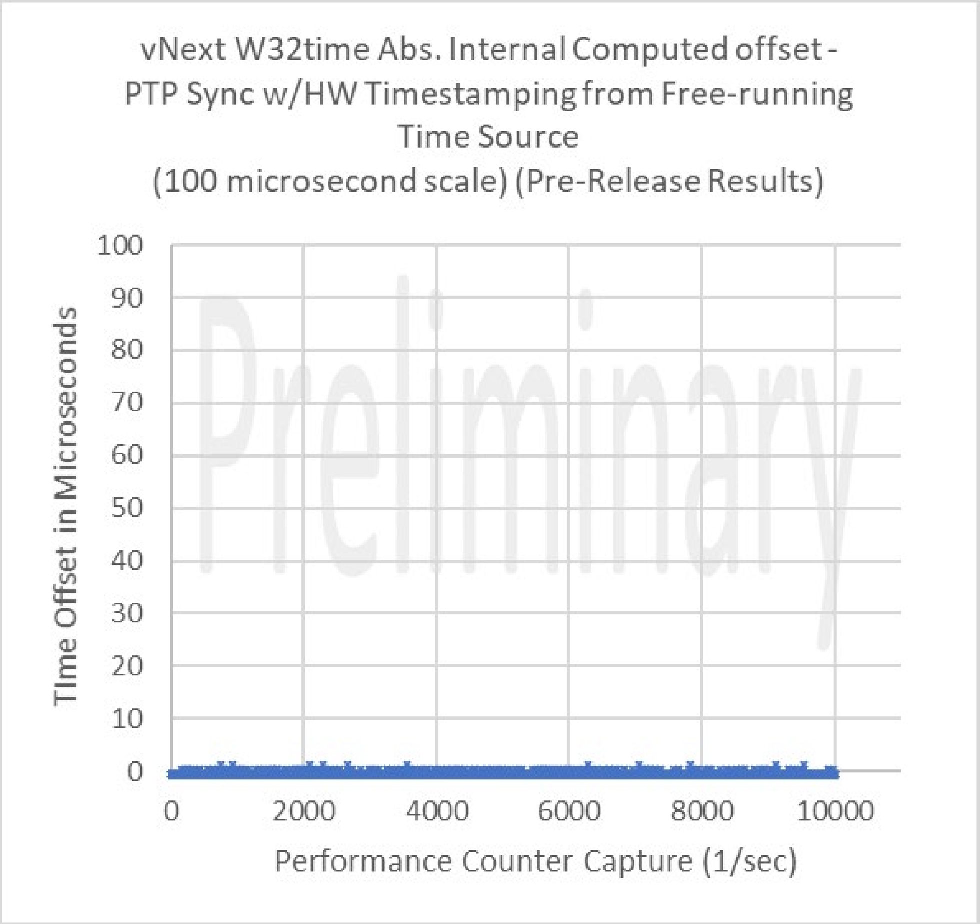
"Computed Time Offset" Performance Counter capture

PTP Sample Offset

PTP Sample Offset Distribution

NTP/PTP – Side-by-Side Comparison #1

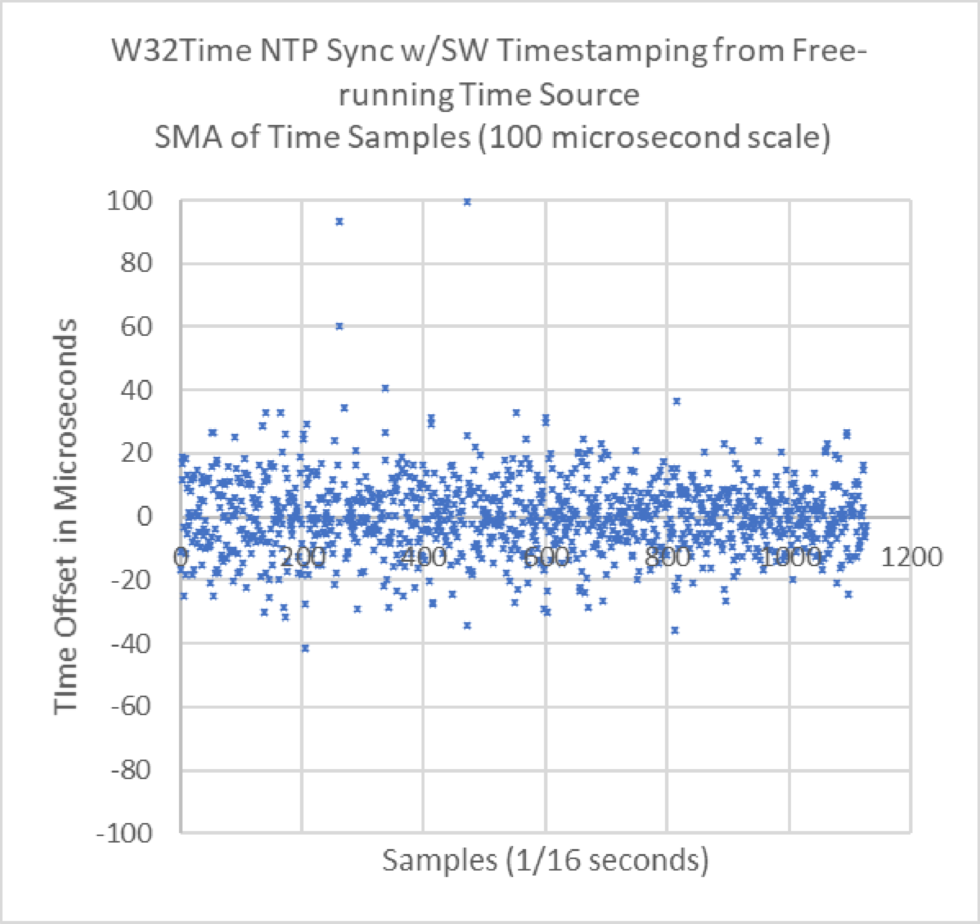


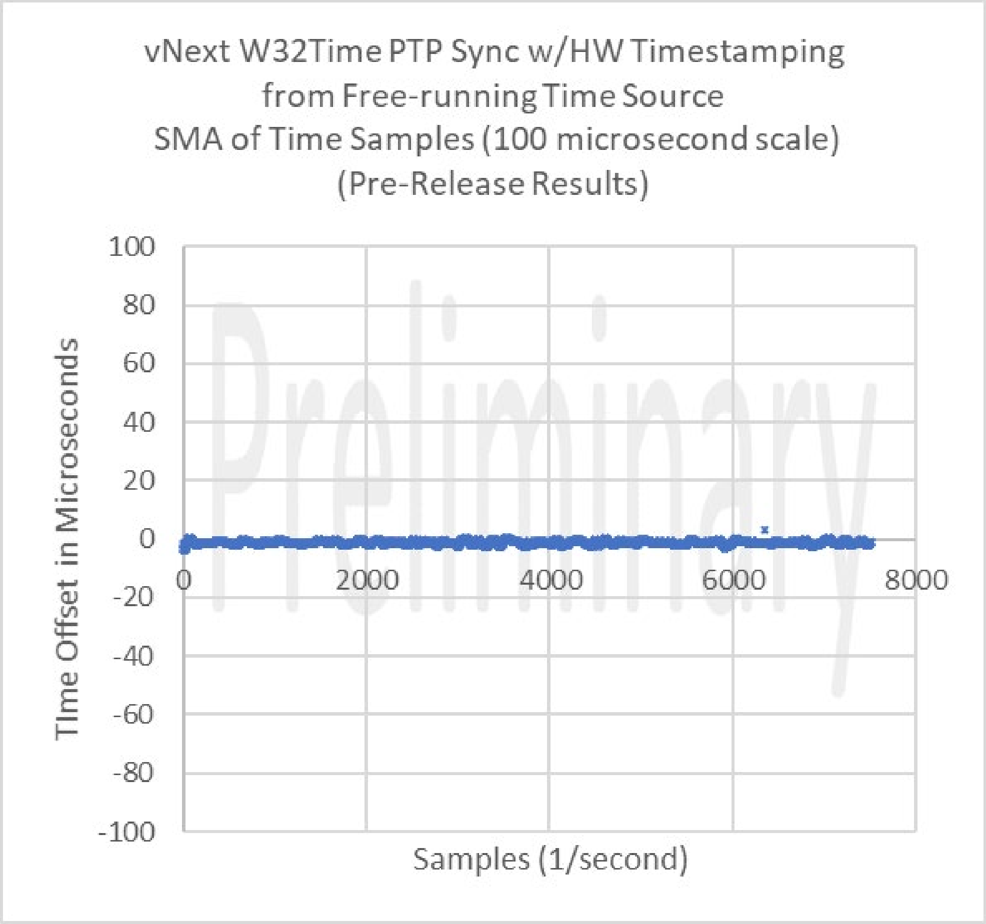


"Computed Time Offset" Performance Counter – Side by side

Improvements due to Hardware Timestamping integration with PTP

NTP/PTP – Side-by-Side Comparison #2

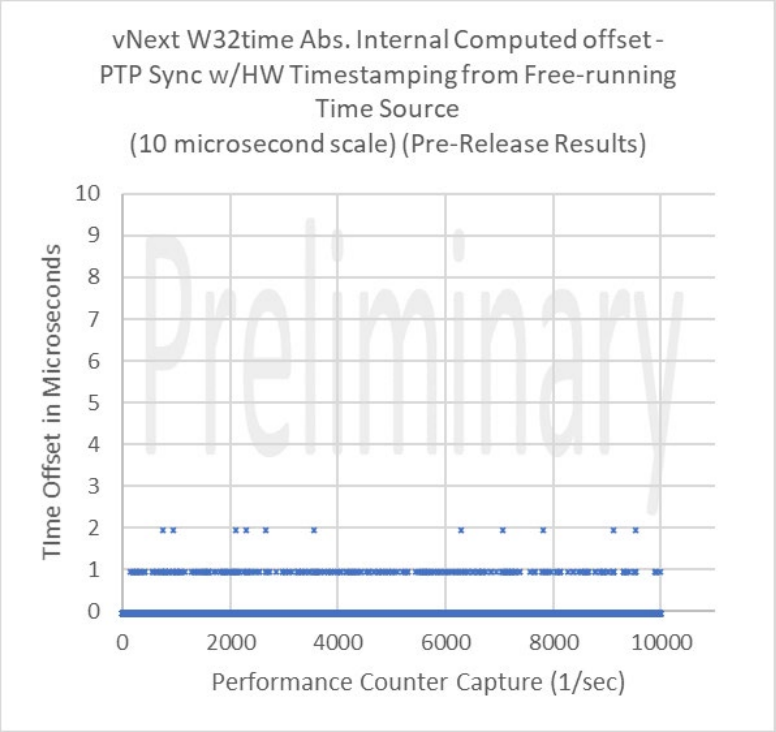


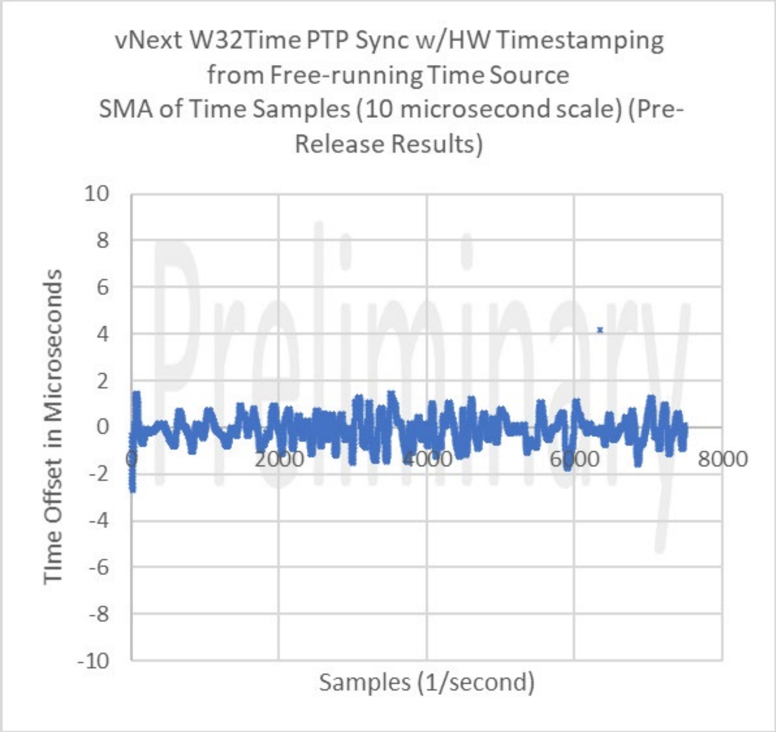


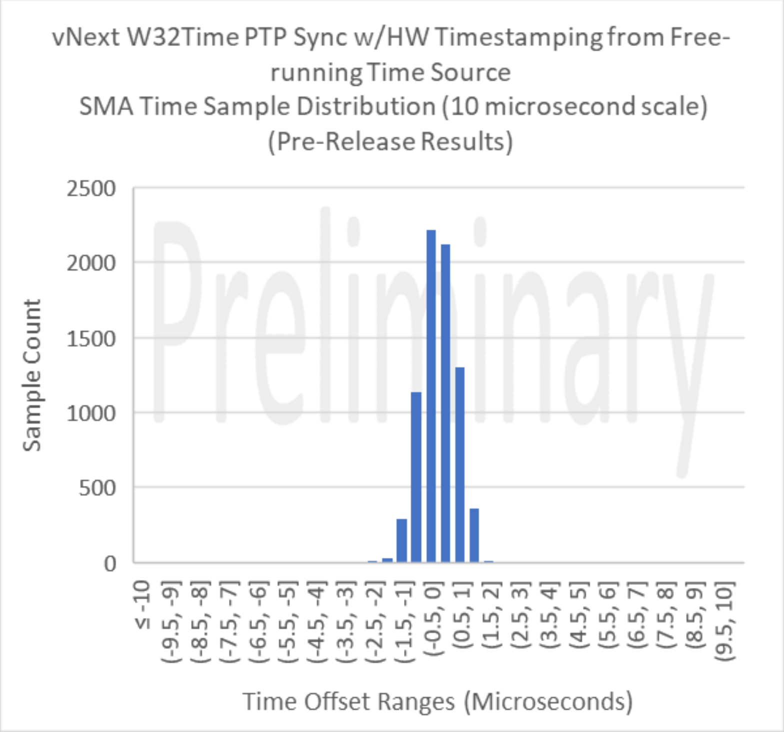
Time Sample Offset Comparison – Side-by-side

Improvements due to Hardware Timestamping integration with PTP

PTP + HW Timestamping Test Results – Closer look @ Best Observed Scenario







"Computed Time Offset" Performance Counter capture

PTP Sample Offset

PTP Sample Offset Distribution

Showcases ±2 µs time offset – This is at least a Kessel Run away from Windows timekeeping from 10 years ago.

Timestamping for Windows Applications

- Windows API for accessing Timestamping functionality in Server Next should be released in due time.

Microsoft Windows Server Next

- Windows Server Next AKA pre-release Windows Server OS is available as part of the Windows Insider program.
  - Refer to the program for specifics: https://insider.windows.com/en-us/
- Time Synchronization is included in the Windows Client and Server OS.
- Stable features from pre-release OS are generally included in next major OS release.

Testing Windows Server Next

We normally would release results from topologies running released OS that could be replicated by our customers for their own time synchronization needs.

We are choosing to share the best results we have observed from Server Next because they have been compelling.

Work on Windows Server Next is still in progress and the time sync performance in the next Server release may be different than what is observed here.

Conclusion

We are excited about the possibility of awesome time sync accuracy in Server Next resulting from the integration of PTP with Hardware Timestamping.

We look forward to publishing detailed guidance and data for wider usage with the next Server release.

We are committed to making the best possible time synchronization widely available for everyone’s use.

Microsoft

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

QUESTIONS: Submit using the questions tab on the control panel located on the right side of your screen.

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Calnex Sponsor Presentation

Tommy Cook
CEO
Calnex Solutions

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Tommy Cook, CEO
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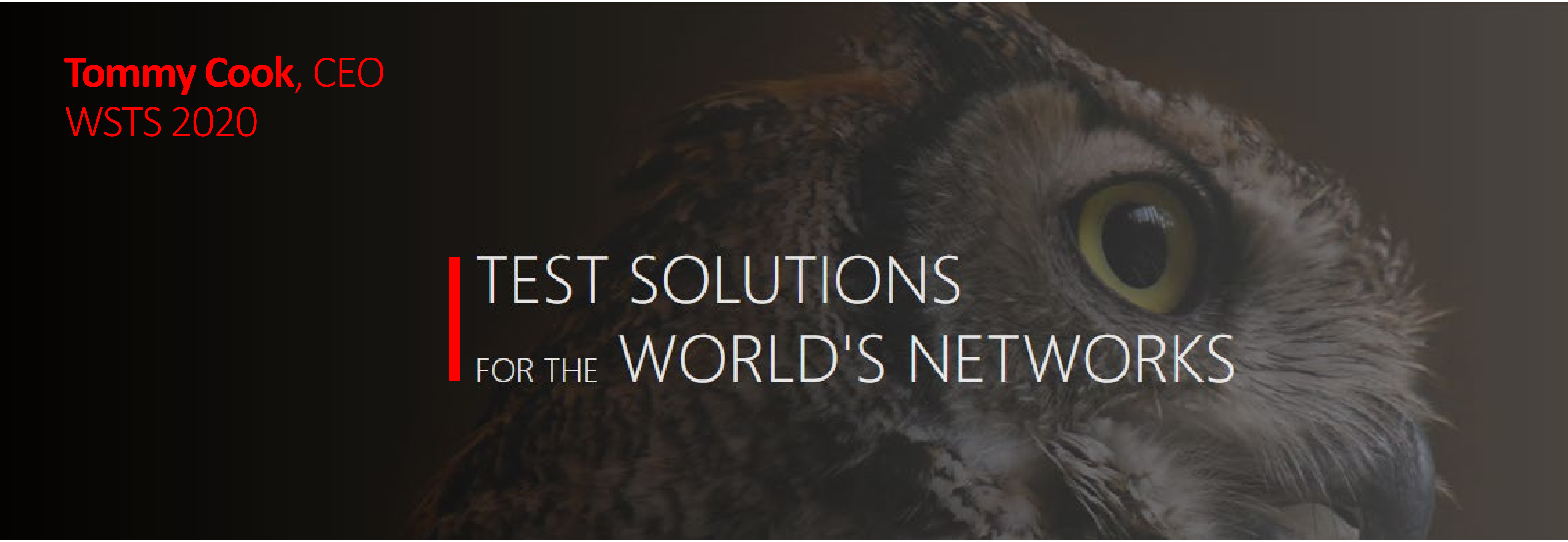

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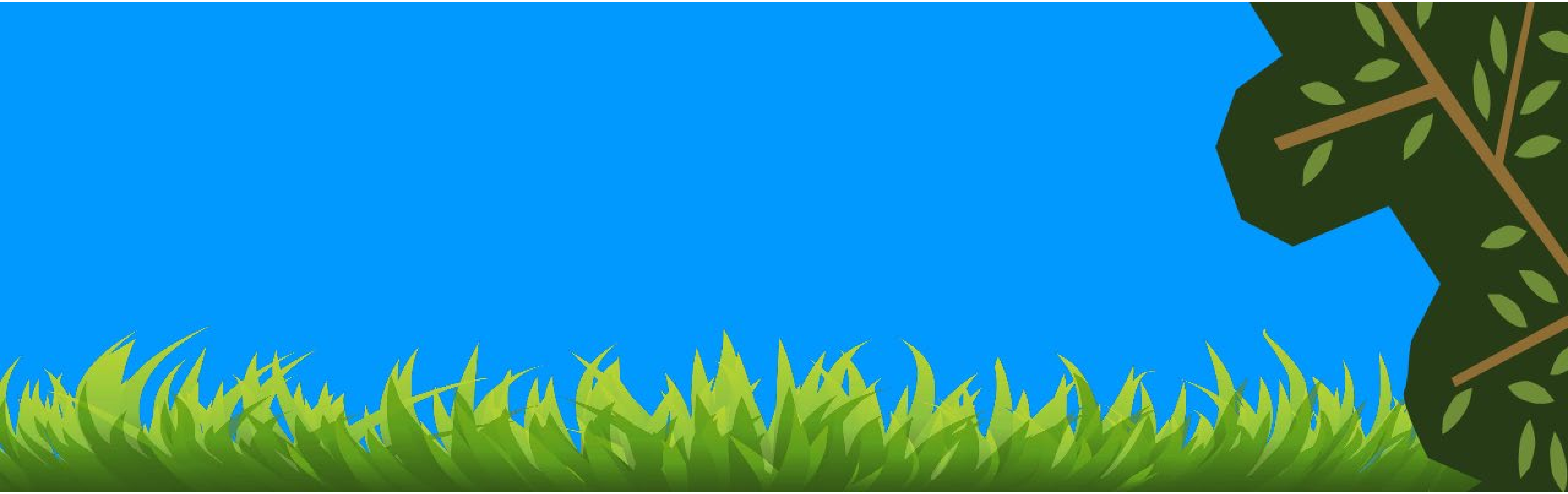
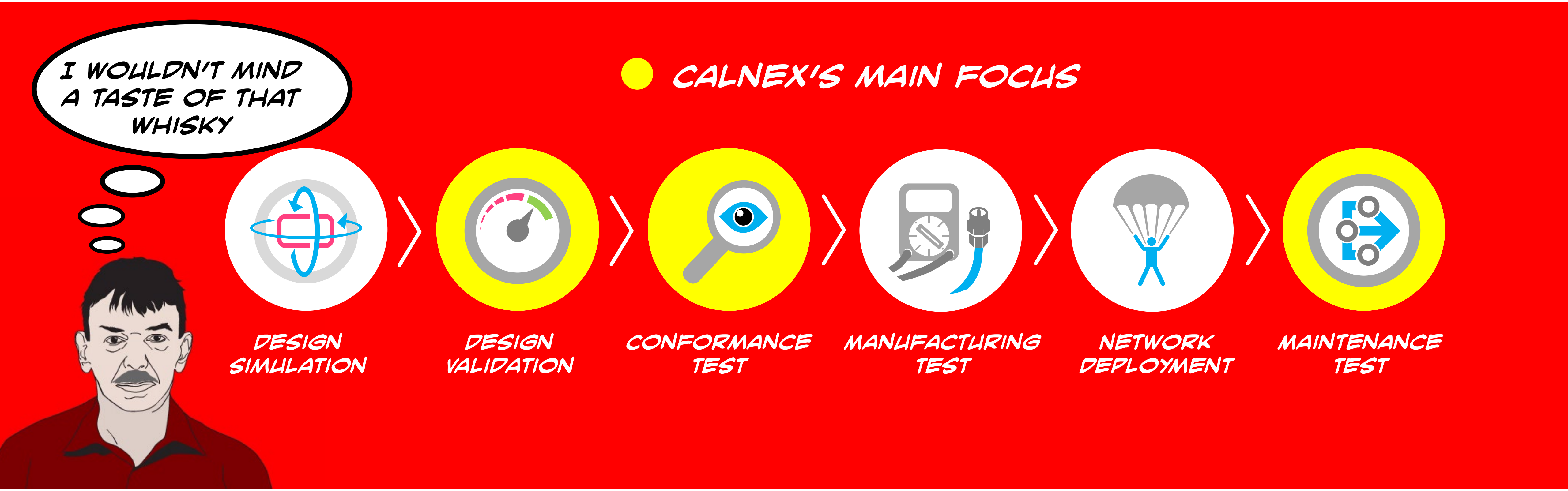


THE WIRELESS INDUSTRY'S DEVELOPMENT LIFECYCLE



HIGH-ACCURACY CLOCKS FOR 5G

CLASS C AND D CLOCKS

NEED A TESTER WITH

SUB-NANOSECONDS PRECISION

HIGH-ACCURACY CLOCKS FOR 5G

PARAGON-NEO

THE WORLD'S ONLY TESTER FOR CLASS C AND CLASS D CLOCKS

DISAGGREGATED PLATFORMS AND WHITEBOXES

HEAPS OF NEW PLATFORMS AND HARDWARE/SOFTWARE VENDORS

DISAGGREGATED PLATFORMS AND WHITEBOXES

CALNEX PROVIDES TEST SOLUTIONS AND EXPERTISE ...

OVER 40 DIFFERENT DISAGGREGATED PLATFORMS 'PROVEN BY CALNEX'

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IT'S A GREAT NEW IDEA

BUT DOES IT ACTUALLY WORK?

NETWORK SLICING

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I'M TOMMY COOK, FOUNDER AND CEO OF CALNEX

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WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Electric Power Applications of Wide-Area Time Synchronized Measurements

Jeff Dagle
Chief Electrical Engineer
Pacific Northwest National Laboratory

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May 13, 2020

PNNL-SA-152936

Electric Power Applications of Wide-Area Time-Synchronized Measurements

<u>Presented to</u>
WSTS Virtual Webinar Series
May 13, 2020

Jeff Dagle, PE

Chief Electrical Engineer
Pacific Northwest National Laboratory
Electricity Infrastructure Resilience
+1(509)375-3629
jeff@pnnl.gov

PNNL is operated by Battelle for the U.S. Department of Energy

Major Takeaways

- An extended loss or degradation of satellite-based timing signals today would not be expected to result in a high-consequence reliability event
- Emerging measurement applications intended to increase reliability and enhance wide-area situational awareness could be impacted
- With the loss of wide-area time synchronization, utilities rely on the internal system clocks' holdover times
  - The stability of the clock's oscillator determines this holdover capability
- Control system applications that require wide-area time synchronization should consider the integrity and robustness of satellite-based timing signals in their design
- In the future, electric system operators will require higher availability, integrity, and redundancy for precise time synchronization

Power System Applications for Precise Timing

Application Area	Time Synchronization Requirement	Application Notes
Control Room Applications	1 s	Data acquisition, supervisory control, state estimation, etc.
Event Recording	1 ms	Sequence of events and disturbance reporting requirements
Synchrophasors	1 µs	Wide-area visibility
Advanced Protection	100 ns	Traveling wave fault location

Industry Standard for Disturbance Monitoring and Reporting Requirements

- The North American Electric Reliability Corporation (NERC) Standard for Disturbance Monitoring and Reporting Requirements
  - NERC Standard PRC-002-2

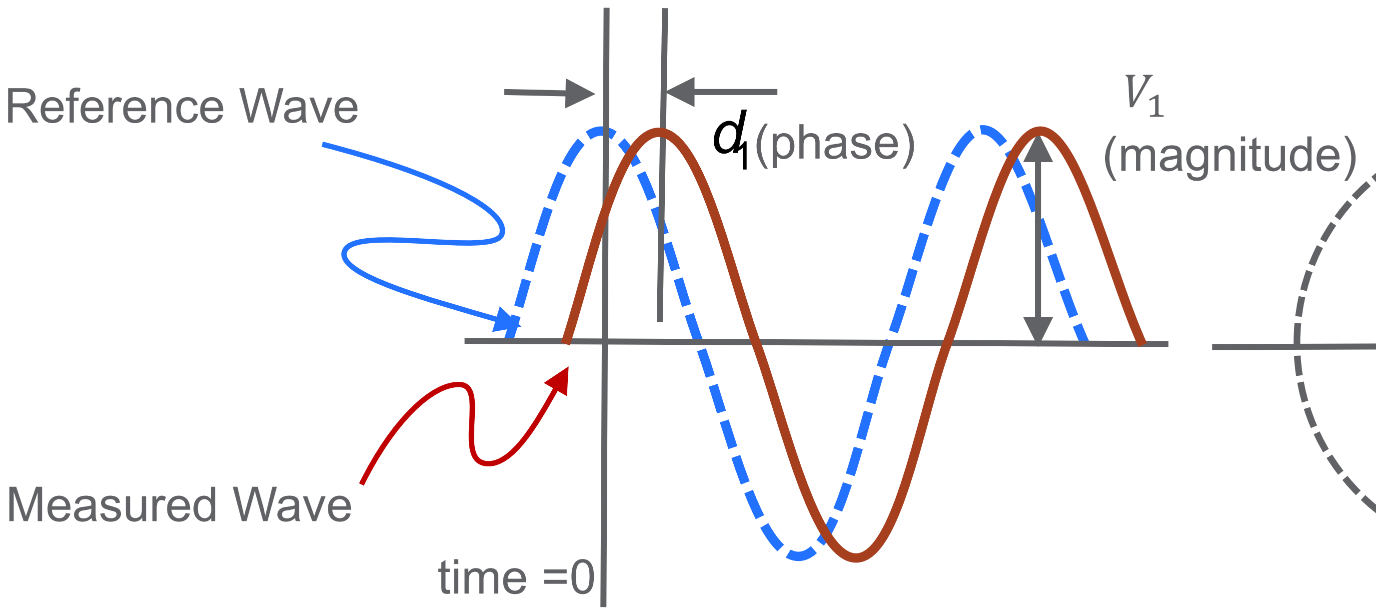
- For all sequence of events and fault recording data:
  - Requirement 10.2: Synchronized device clock accuracy within ± 2 milliseconds of UTC

- This applies to all dynamic disturbance recording data that is required by the standard

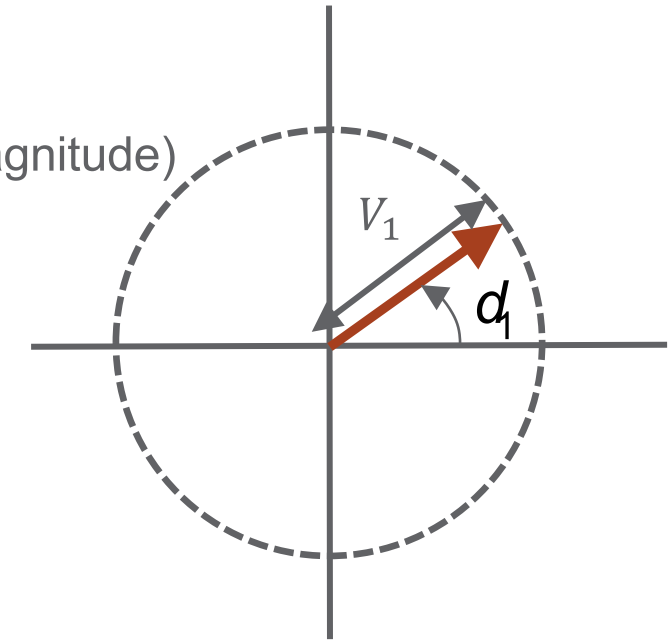
What is a "Phasor"?

- A phasor *represents* magnitude and phase angle of a sinusoidal wave

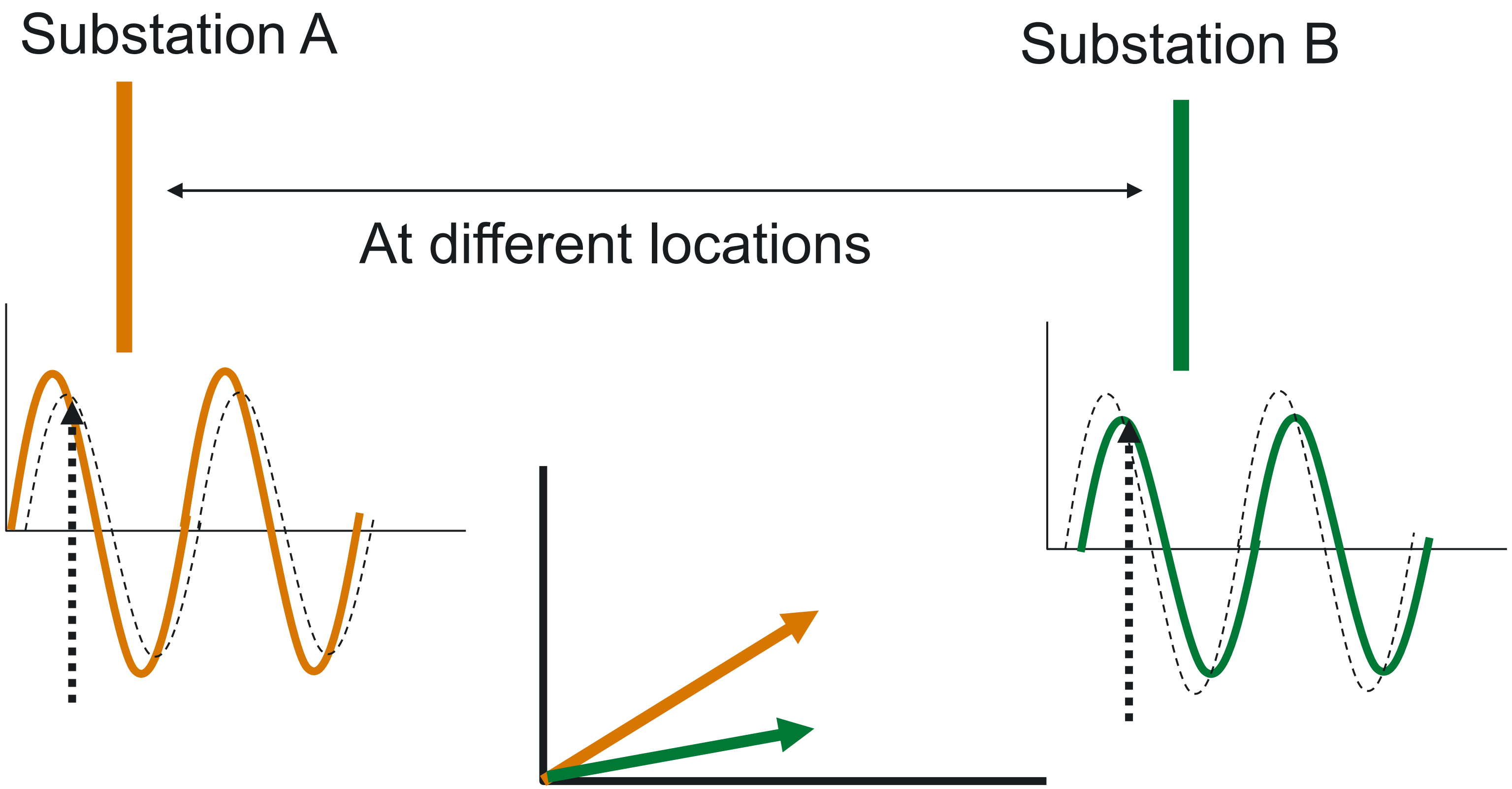
Sinusoidal Waveform



Phasor Representation



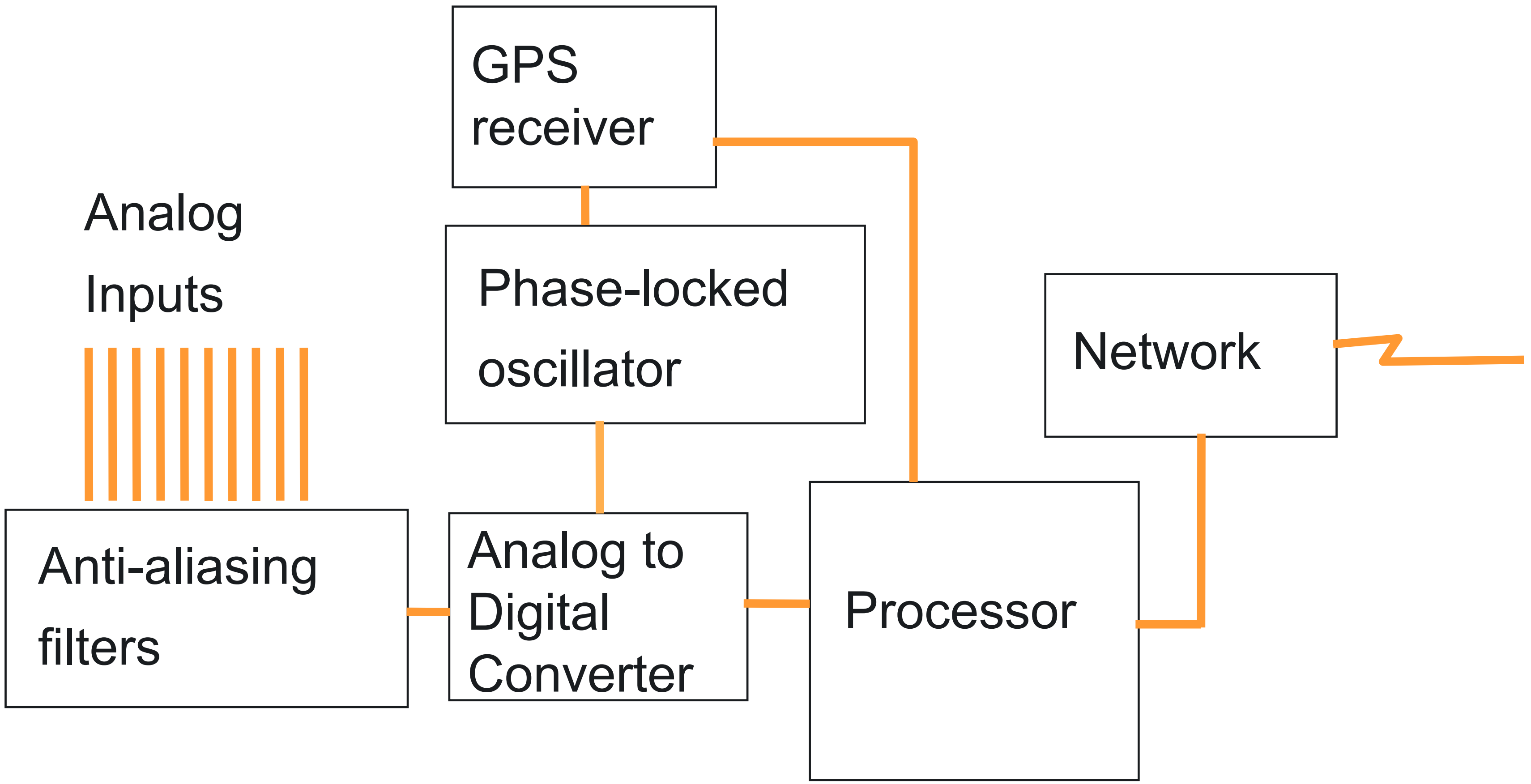
Time Synchronized Measurements



By synchronizing the sampling processes for different signals, which may be hundreds of miles apart, it is possible to put their phasors on the same phasor diagram.

Credit: A.G. Phadke

Phasor Measurement Unit (PMU)

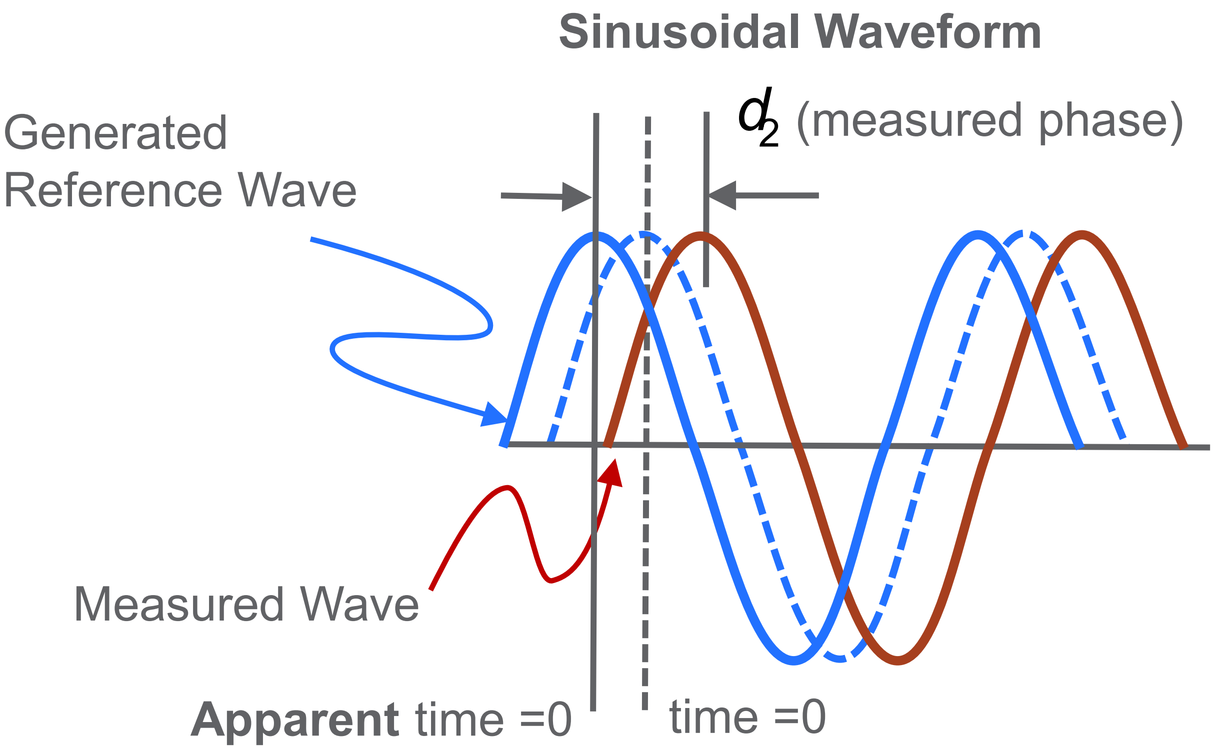


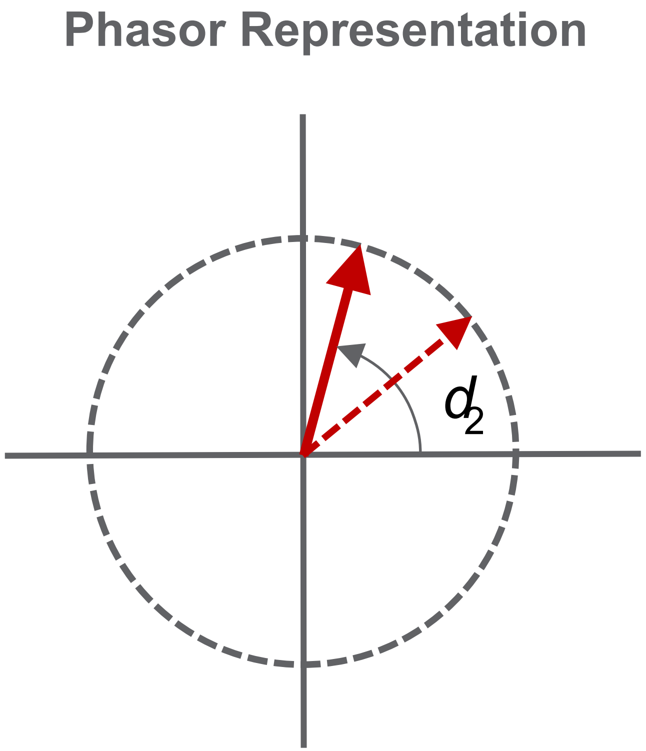
Except for synchronization, and some post processing, the hardware is the same as that of a digital fault recorder or a digital relay.

Credit: A.G. Phadke

PMU Time Synchronization Accuracy

- The *measured* angle is determined by the time reference
- At 60Hz, 1° phase angle precision corresponds to 46 µs
- Magnitude and frequency are not affected





Different Types of PMUs

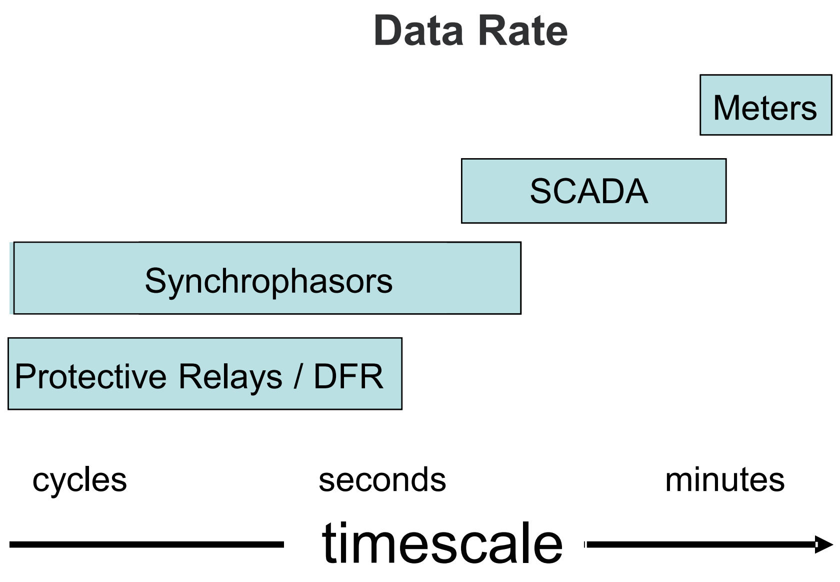
Governed by IEEE Standards:

- P class (protection)
  - Minimal filtering
  - Possible aliasing of higher frequency components
  - Less delay in estimation
  - Important for real-time controls requiring minimum delay

- M class (measurement)
  - Better anti-alias protection
  - More filtering deceases effect of higher frequencies, noise
  - Latency longer (depends on reporting rate)
  - Important for situations with higher frequencies present

Technology to Meet Emerging Industry Needs

- Synchrophasor technology is being rapidly deployed by utilities throughout the world
- Both on-line and off-line applications are emerging, particularly those that require faster time-synchronized measurements than are available from existing technology
- Vendors are providing new solutions including measurement technology, networking, and applications



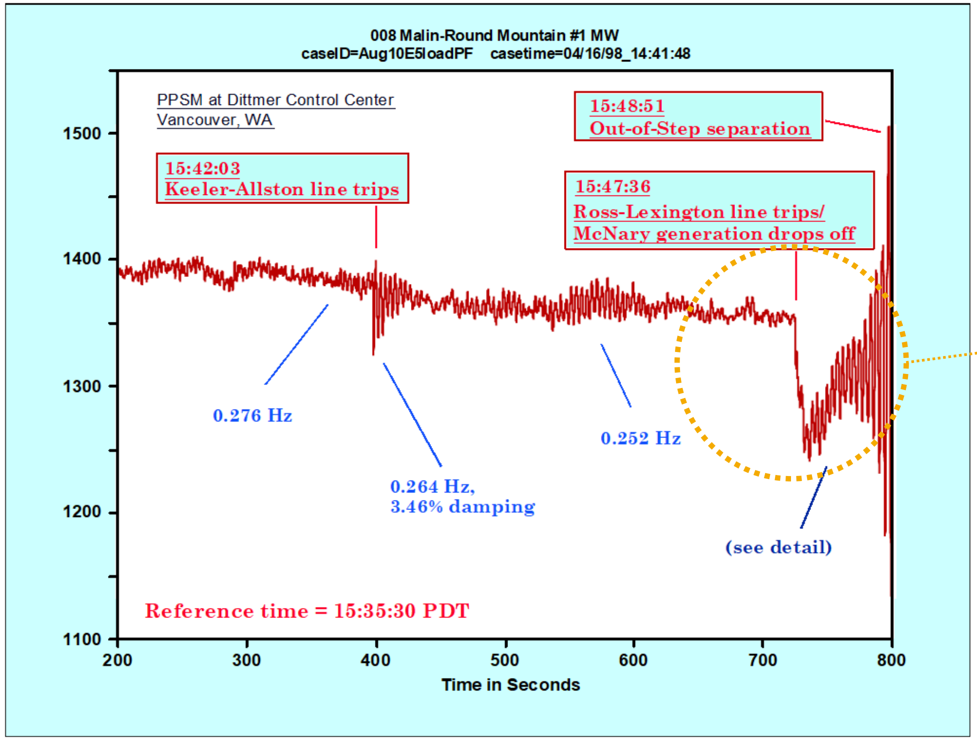
Time synchronized data can be gathered at reporting rates much faster than traditional supervisory control and data acquisition (SCADA) systems

They provide the "missing link" between localized digital fault recorders (DFR) and SCADA systems.

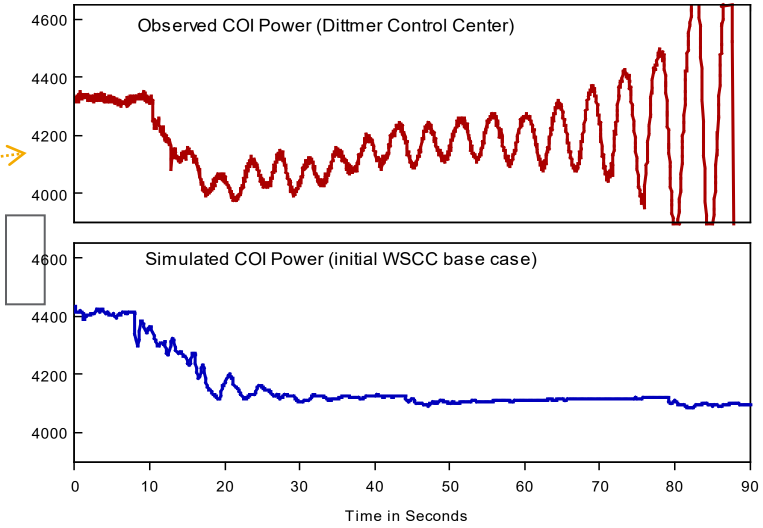
Unlike most SCADA systems, these emerging wide-area measurement technologies utilize Internet protocols to exchange measurement information.

Lessons Learned from the August 10, 1996 Western Blackout

High-speed, time-synchronized data was essential to support the blackout investigation



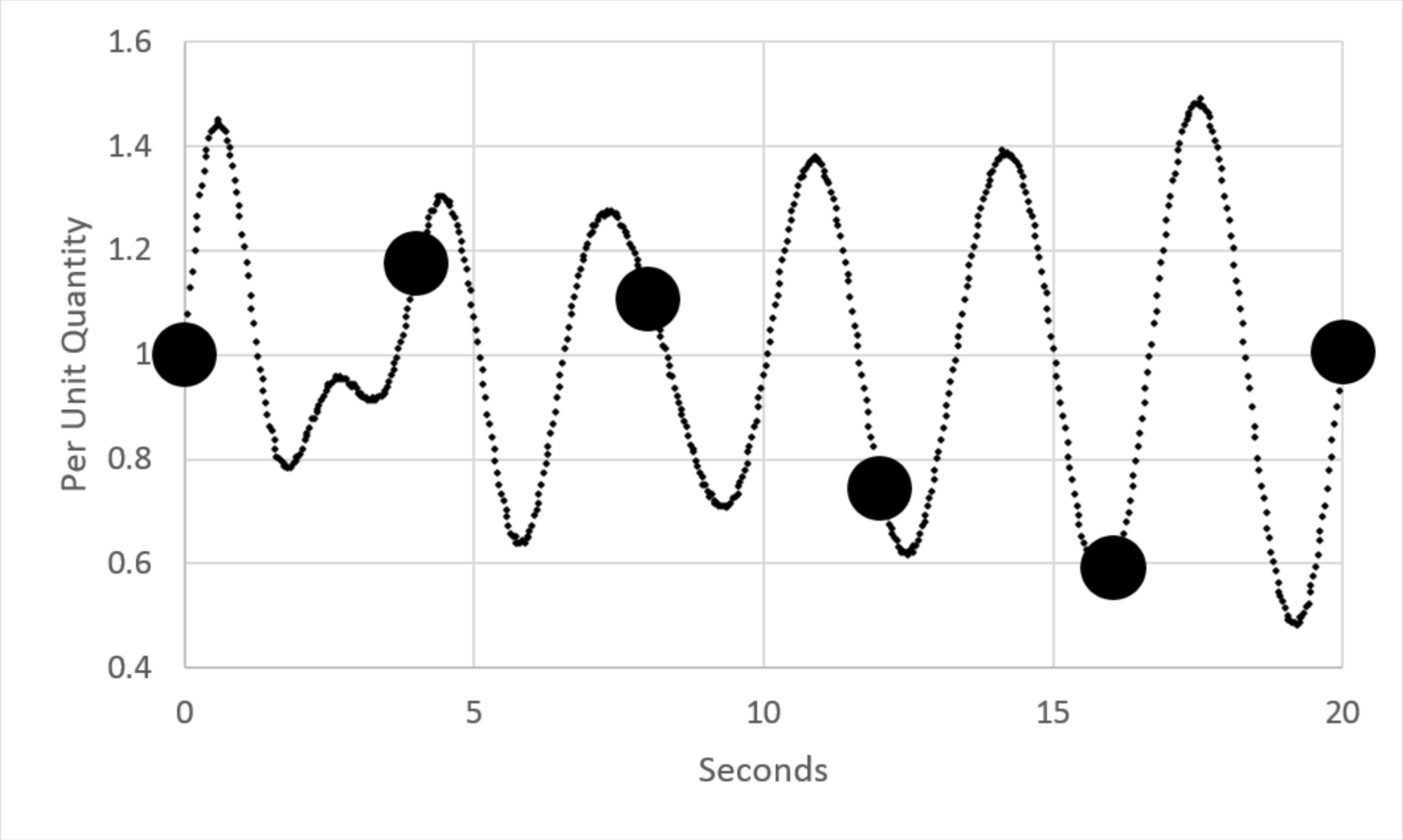
The need for better model validation was demonstrated



Notional representation of the difference between synchrophasors and traditional SCADA measurements

Supervisory Control and Data Acquisition (SCADA): every 4 seconds

Synchrophasors: typically 30 measurements per second



Synchrophasor Applications for Wide-Area Monitoring, Analysis, and Control

Monitoring	Analysis	Control
• Frequency • Voltage • Oscillation Detection • Wide-Area Visualization • Operator Decision Support • State Estimation (hybrid or linear state estimation / state measurements) • Renewables Integration	• Post-Event Analysis • Model Validation • State Estimation	• Adaptive Islanding • Adaptive Relaying • Power System Stabilizing / Power Oscillation Dampers • Black-Start Restoration • Automated Remedial Action Schemes

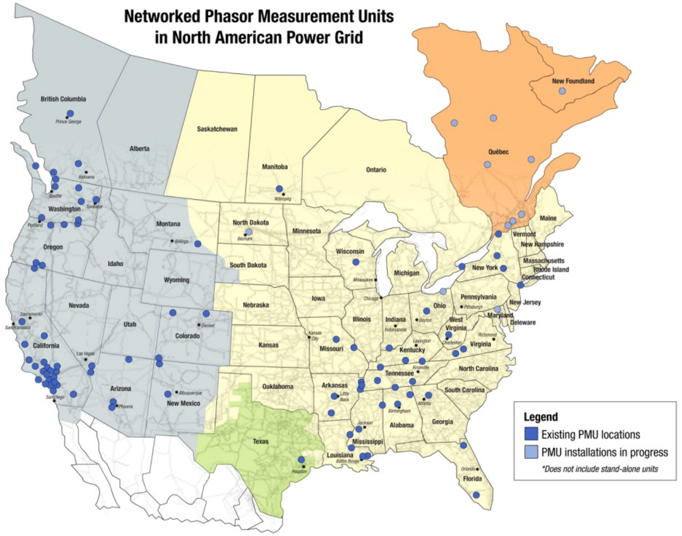
The North American SynchroPhasor Initiative (NASPI)

The U.S. Department of Energy (DOE) and EPRI are working together closely with industry to enable wide-area time-synchronized measurements that will enhance the reliability of the electric power grid through improved situational awareness and other applications.

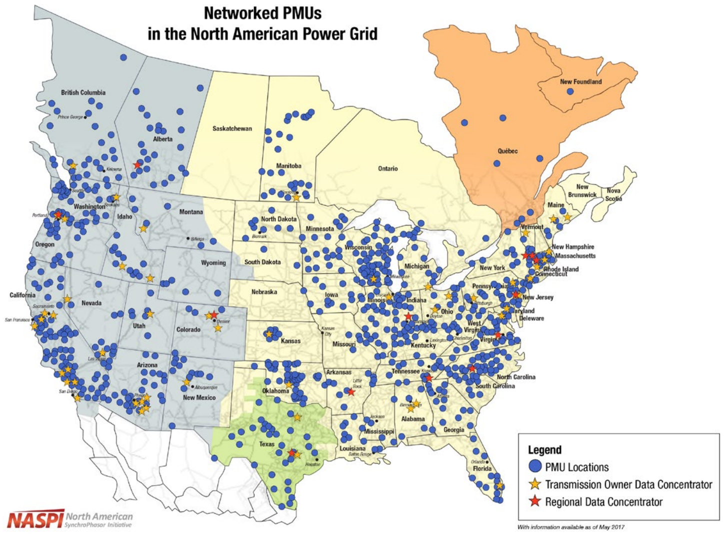
Current and emerging areas of emphasis/focus for NASPI:

- Networking and communications technologies (advanced architectures)
- Statistical analysis and deep learning for extracting actionable information from large datasets
- High-resolution sensors to characterize the transient behavior of inverter-based resources and other fast-acting phenomena

April 2007



May 2017



"Better information supports better - and faster - decisions."

NASPI North American SynchroPhasor Initiative | U.S. DEPARTMENT OF ENERGY | Office of ELECTRICITY | EPRI ELECTRIC POWER RESEARCH INSTITUTE

NASPI Current Status

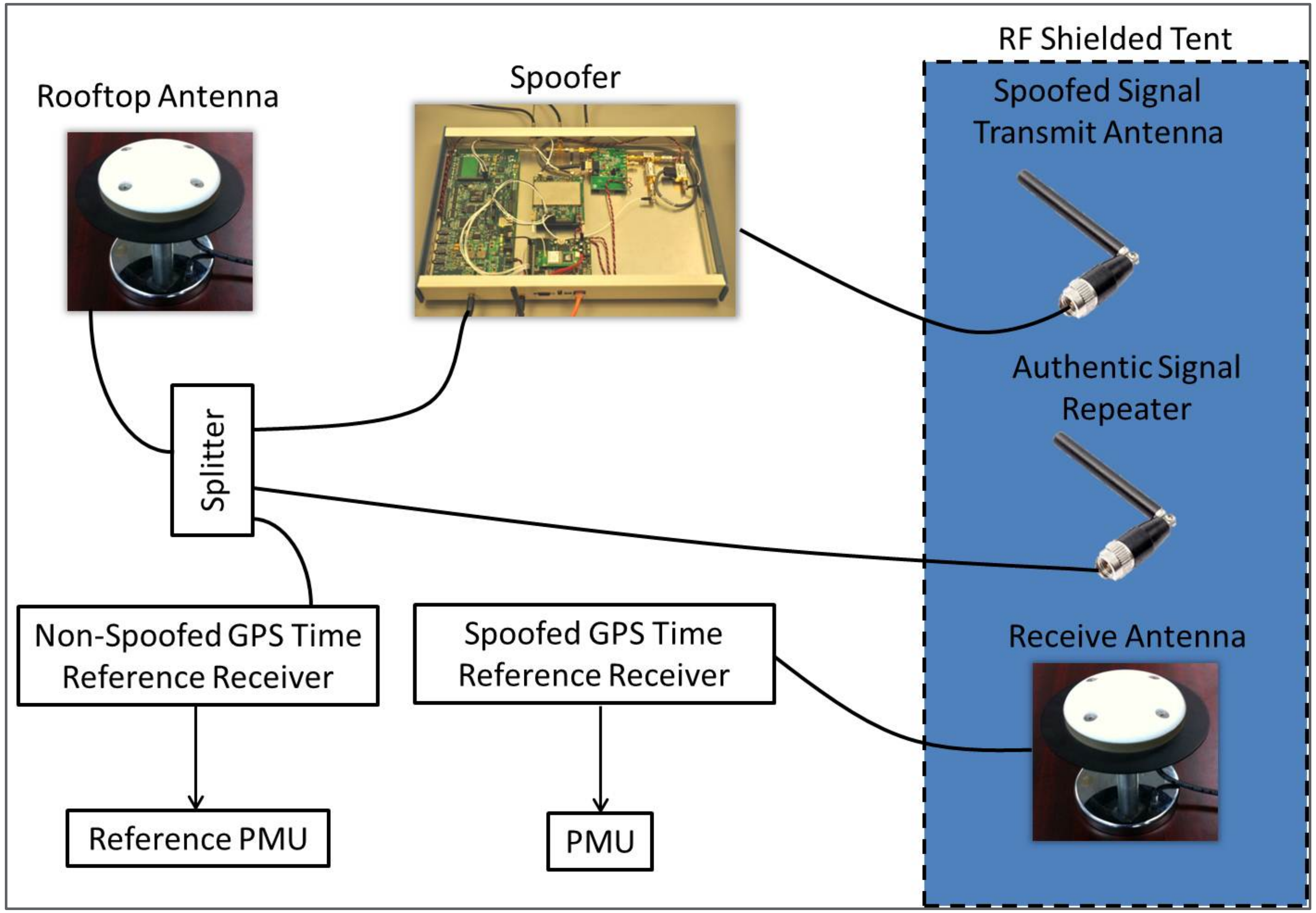
- Technical Task Teams (comprised of, and led by, key industry stakeholders)
  - Control Room Solutions
  - Data & Network Management
  - Distribution
  - Engineering Analysis
  - Performance Requirements, Standards & Verification
- Work Group Meetings
  - Most recent: October 2019 in Richmond, VA
    - ✓ Train the trainer workshop
    - ✓ Sharing best practices and lessons learned
    - ✓ Vendor exhibits, poster session, organization updates, and other technical presentations
  - April 2020 meeting converted to four one-hour webinars on 4/15-16
  - Upcoming: November 4-5, 2020 in Minneapolis, MN
- New monthly webinar series initiated

Testing Vulnerabilities Associated with Satellite Clocks for Precision Timing Applications in the Power System

Test Objectives:

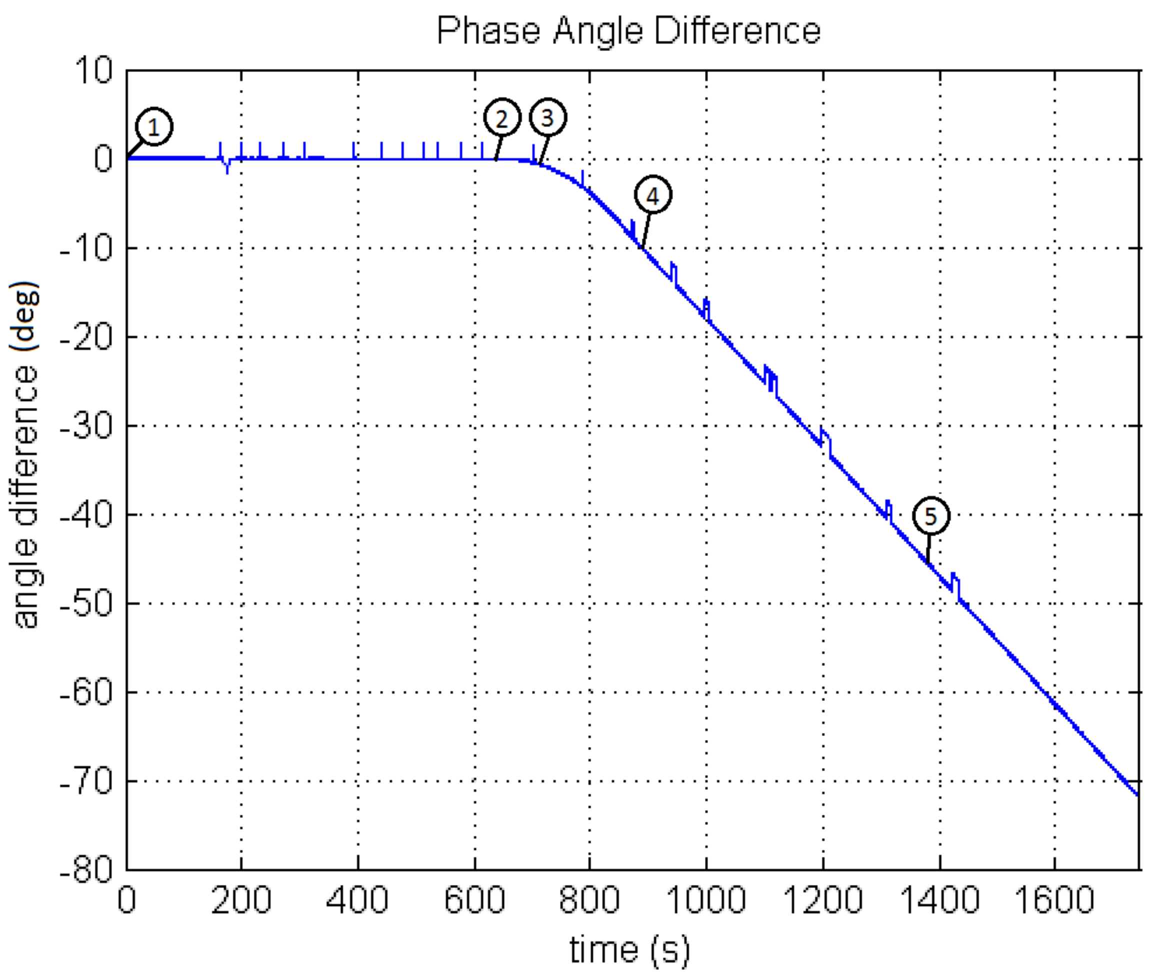
- Determine the susceptibility of GPS satellite clocks to spoofing that could undermine the accuracy of Phasor Measurement Units (PMU)
- Tests carried out at the PNNL Electricity Infrastructure Operations Center (EIOC) December 2011 with Northrop Grumman and University of Texas-Austin
- Three different satellite clocks were utilized in the testing

Schematic of the Test Setup



RF Shielded Tent

Spoofing Test Result: Impacting the Phase Angle Measurement by Manipulating the Time Reference



Test Results

- All three satellite clocks that we tested were susceptible to GPS spoofing
  - Some differences in the rate of change that could be implemented (defeating the internal error checking algorithms)
  - Some differences in how the clocks responded when the spoofing signal was turned off
- Recommending an alternative method for time synchronization associated with control applications that require robust and secure time synchronization

Jamming Satellite Clocks

- Jamming is easier to accomplish than spoofing
- Consequences are much less impactful:
  - Clocks will reliably set the “loss of synchronization” error flag
  - Time error will be based on internal clock holdover accuracy
  - Resulting timing errors will be somewhat random
  - Predictable behavior of the clock when jamming signal removed

Options for Increasing Time Synchronization Robustness

- Enhancing the satellite-based timing system
- Improved holdover oscillator accuracy
- Atomic clocks at substations
- Alternative radio-based technology (e.g, eLORAN)
- Network-based time synchronization
  - For example: Precision Time Protocol (IEEE Standard 1588)

NASPI Path Forward

- Continue to support and liaison with industry
  - Various IEEE Standards activities
  - North American Electric Reliability Corporation
    - ✓ Synchronized Measurement Subcommittee
  - Western Electricity Coordinating Council
    - ✓ Joint Synchronized Information Subcommittee
- Anticipating no substantial structural changes to the NASPI leadership team, industry-led task teams, or meeting tempo (plan to resume twice per year)
  - Maintain approximately equal representation among utilities, vendors, and academia, which has been a unique attribute and key value proposition for NASPI
- Current and emerging areas of emphasis/focus for NASPI:
  - Networking and communications technologies (advanced architectures)
  - Statistical analysis and deep learning for extracting actionable information from large datasets
  - High-resolution sensors to characterize the transient behavior of inverter-based resources and other fast-acting phenomena

New NASPI White Paper

High-Resolution, Time-Synchronized Grid Monitoring Devices

- Power system planners and analysts see growing opportunities in the use of higher-resolution, time-synchronized grid data for a variety of applications
- This paper defines high-resolution measurements as those based on samples obtained at rates faster than 256 samples/second, ranging up to a million samples/second (1 MHz)
  - Reviews the types of devices that can make such measurements
  - Addresses the more valuable applications for high-speed, time-synchronized use cases and considers where on the grid such applications might best be implemented.

Available on the NASPI website: https://www.naspi.org/node/819

Conclusions

- Synchrophasors have long been used for important applications, such as validating power system dynamic models
- There are emerging applications being deployed that utilize synchrophasors for operational applications
- Various deployment initiatives are underway that will continue to introduce advanced technology to solve planning and operational challenges
- There is an emerging need to support higher availability, integrity, and redundancy for precise time synchronization

https://www.naspi.org/

Thank you

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Resilient Time Synchronization for the Energy Sector: Evaluation of Mitigation Technologies

Gerardo Trevino
Technical Leader
Electric Power Research Institute

Sponsored by: Calnex

Session 2: Timing in Finance, Electric Power and Broadcast
May 13, 2020

Resilient Time Synchronization for the Energy Sector

Evaluation of Mitigation Technologies

Gerardo Trevino
Technical Leader Cybersecurity

Workshop on Synchronization and Timing Systems
Virtual Webinar Series
May 13, 2020

Agenda

- Background
- Resilient Time Synchronization for the Energy Sector
  - EPRI Survey Results
  - Supplemental Projects
  - Interest Group
- Next Steps

Background

- GPS is vulnerable* – 3 types
  1. Naturally occurring
  2. Unintentional (interference)
  3. Intentional (jamming or spoofing) – EASY!

GPS is used by the electric sector to provide time data therefore….

energy sector is vulnerable

Background - Moving towards faster response times

More Utility Applications Rely on Precision Timing Enabled by Network-Based Architectures

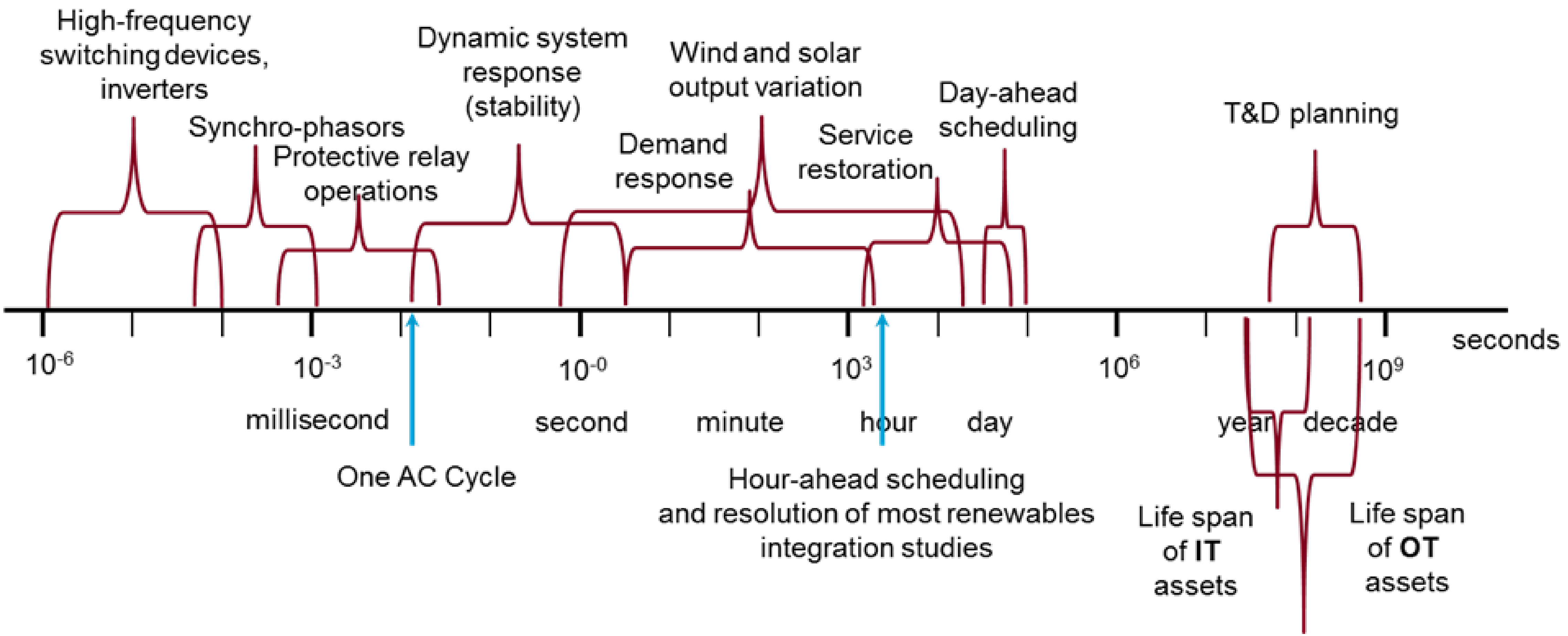
- Substation Automation
- Sampled Values (SV)
- Fault Location
- T&D Relays
- Teleprotection
- Telecommunications networks (i.e. MPLS)
- UAVs
- Synchrophasors (PMUs)
- Network time distribution technologies (i.e. PTP)
- Transition from SONET to modern telecommunications
- New GPS technologies (clocks, detection)

Precision Timing Vulnerabilities

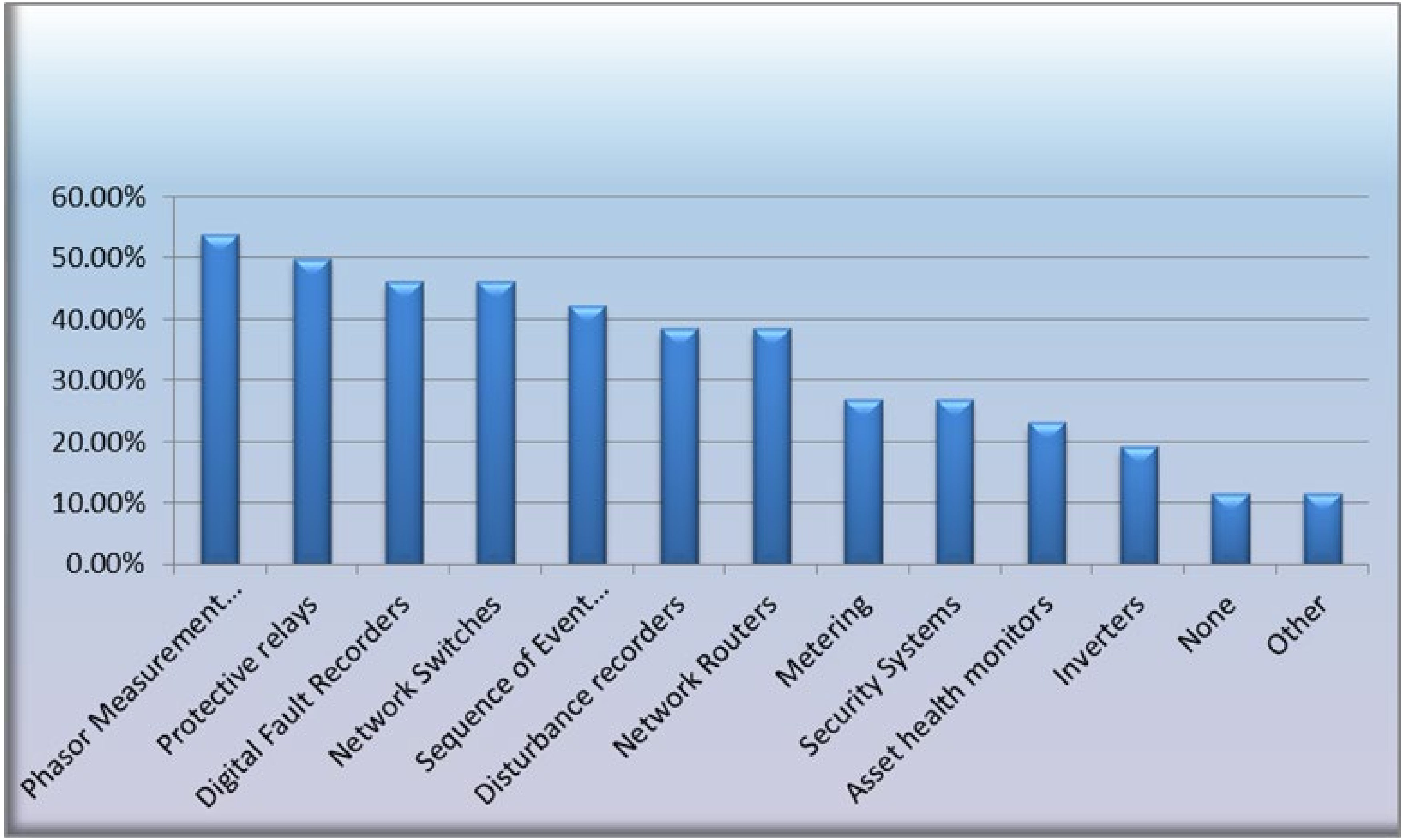
- Timing Drift (natural or intentional)
- Network attacks

EPRI Time Synchronization Survey Results

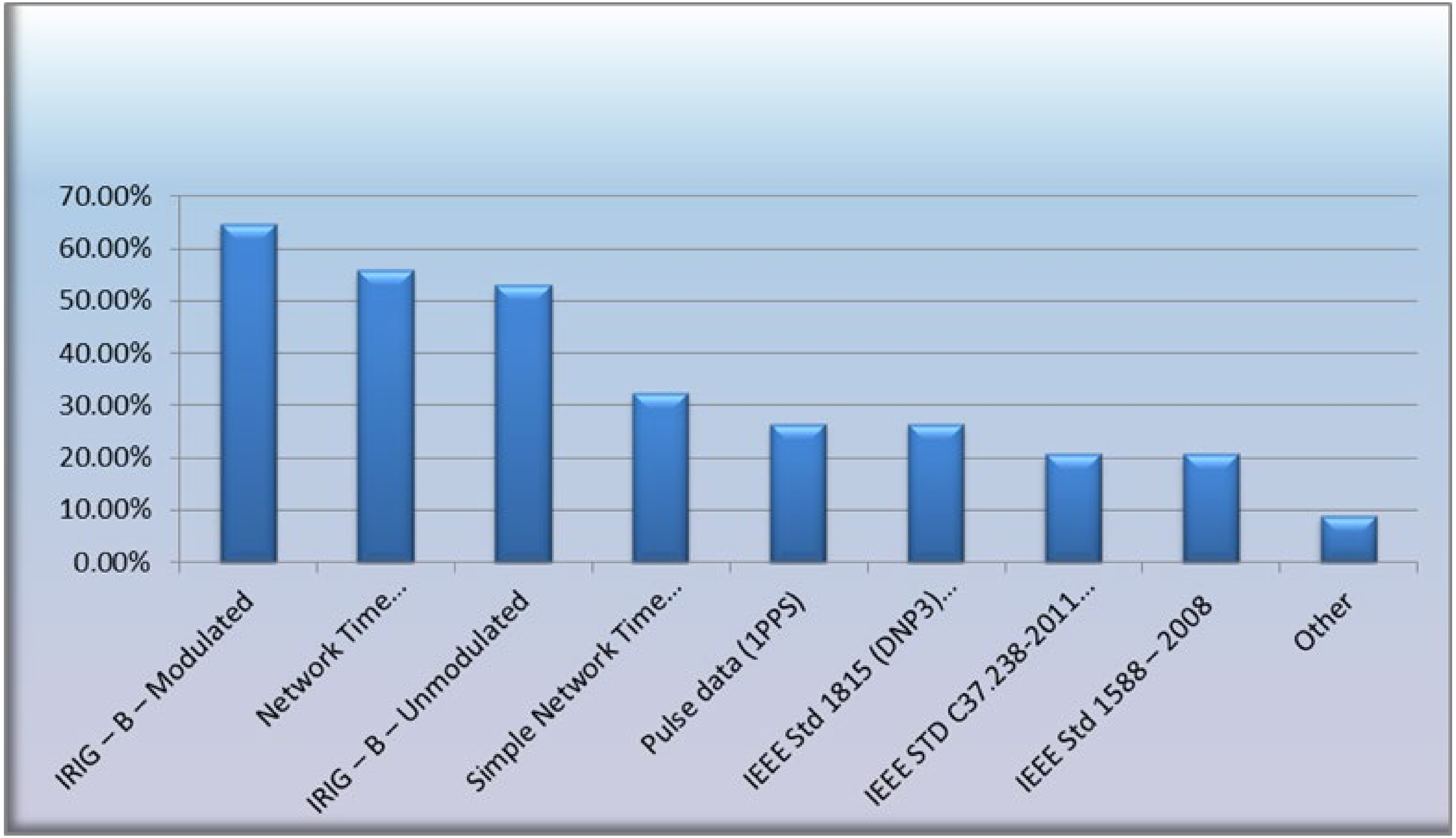
Utility Data Spans a Wide Time Scale



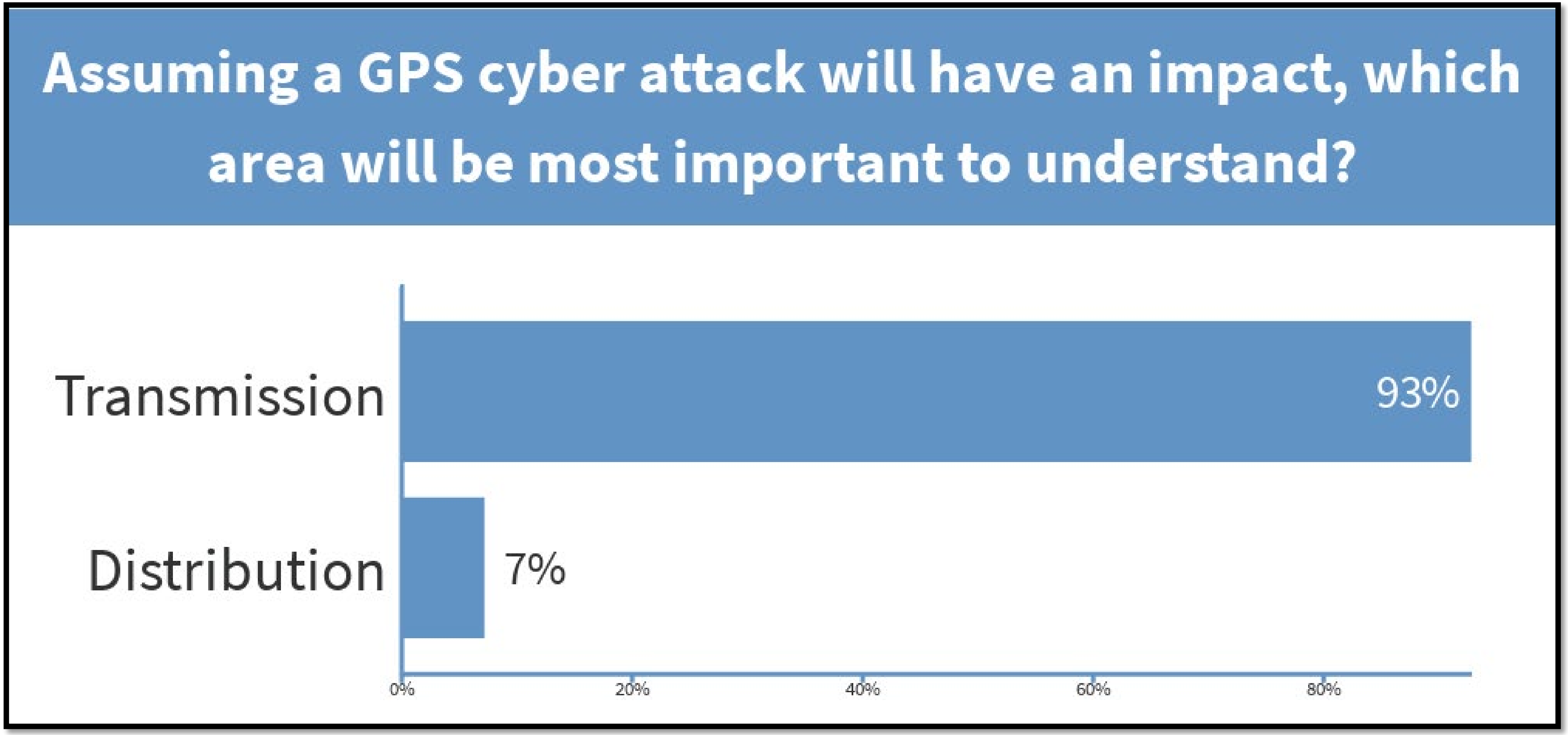
Additional assets planned for connection to the precision time source in the next 5 years



Time distribution protocols / signals currently used



EPRI Meeting Poll – Cyber Security Tech Transfer 2018



Industry Trends

Based on the survey we identified the following trends:

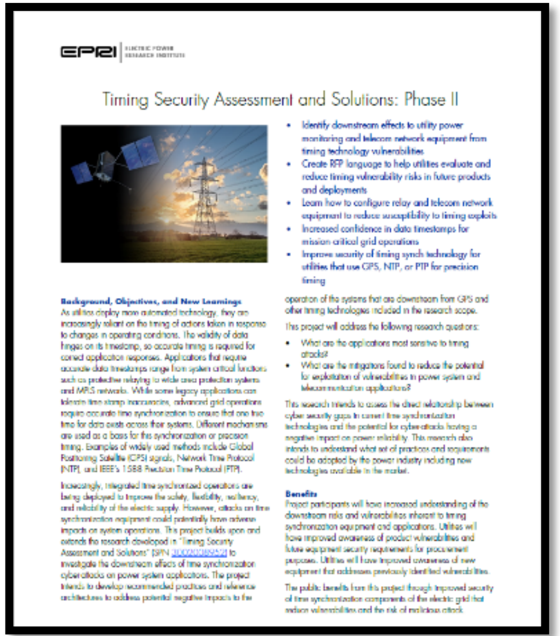
- Over the next five years there is a significant planned increase in the use of the network based precision time protocol (PTP) as defined in IEEE Std c37.238 and IEEE Std 1588.
- Utilities moving away from SONET technologies and incorporating packet based technologies
- Many utilities plan to increase the use of precision time over the next five years for synchrophasor measurement, network routers, network switches, asset health monitors, inverters and security systems.

Resilient Timing Research

ELECTRIC POWER RESEARCH INSTITUTE

Timing Security Assessment and Solutions

- Increased security of power delivery equipment
- Increased security for the management of grid-integrated renewable and microgrid resources
- Increased data veracity and confidence in data
- Improvements in power delivery due to increased acceptance of system optimization technologies
- Consensus-built mitigation tactics and practices



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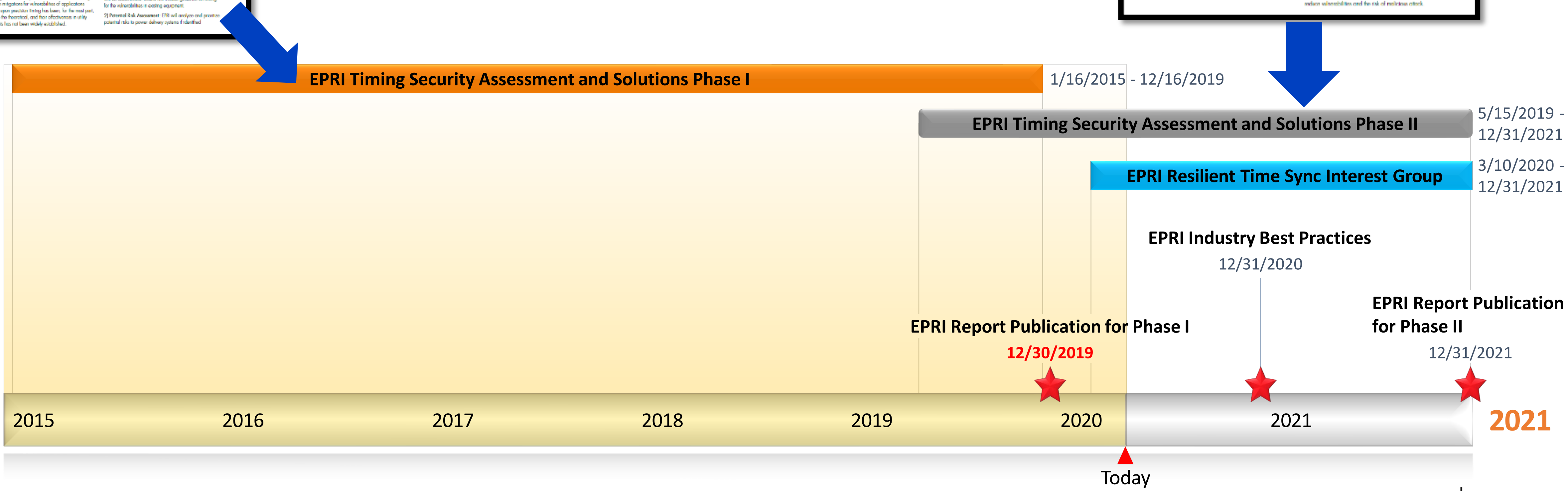
Timing Security Assessment and Solutions: Phase II

- Identify downstream effects to utility power monitoring and telecom network equipment from timing technology vulnerabilities
- Create RFP language to help utilities evaluate and reduce timing vulnerability risks in future products and deployments
- Learn how to configure relay and telecom network equipment to reduce susceptibility to timing exploits
- Increased confidence in data timestamps for mission critical grid operations
- Improve security of timing synch technology for utilities that use GPS, NTP, or PTP for precision timing



Time Security Assessment and Solutions Project Information

Phase I (2016-2019)

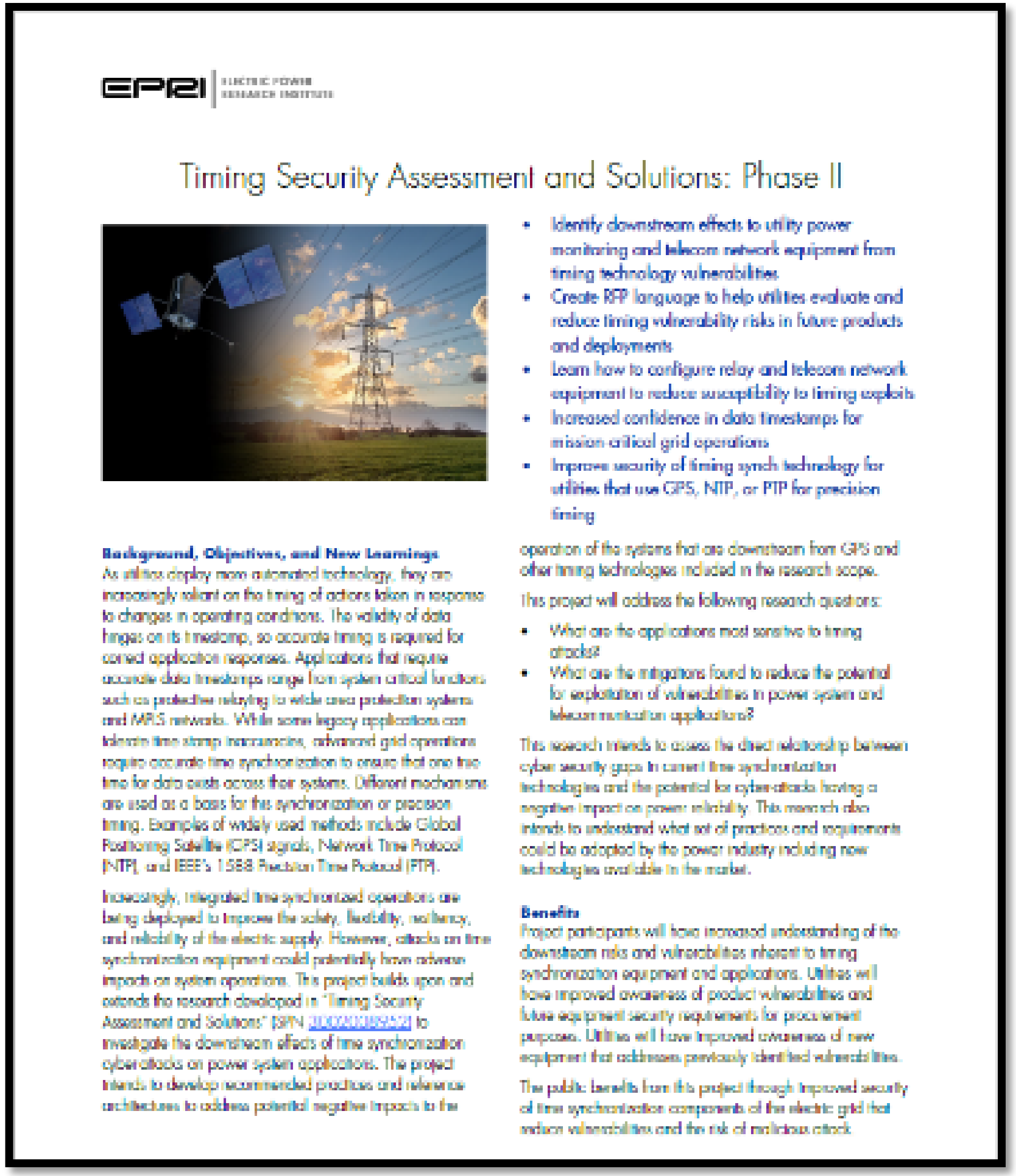
Project Abstract Link:

https://www.epri.com/#/pages/product/3002008952

Phase II (2019-2020)

Project Abstract Link:

https://www.epri.com/#/pages/product/3002016546/



EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Timing Security Assessment and Solutions: Phase II

- Identify downstream effects to utility power monitoring and telecom network equipment from timing technology vulnerabilities
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- Increased confidence in data timestamps for mission-critical grid operations
- Improve security of timing synch technology for utilities that use GPS, NTP, or PTP for precision timing

Background, Objectives, and New Learnings

As utilities deploy more automated technology, they are increasingly reliant on the timing of actions taken in response to changes in operating conditions. The validity of data hinges on its timestamp, so accurate timing is required for correct application responses. Applications that require accurate data timestamps range from system critical functions such as protective relaying to wide area protection systems and MPLS networks. While some legacy applications can tolerate time stamp inaccuracies, advanced grid operations require accurate time synchronization to ensure that one true time for data exists across their systems. Different mechanisms are used as a basis for this synchronization or precision timing. Examples of widely used methods include Global Positioning Satellite (GPS) signals, Network Time Protocol (NTP), and IEEE's 1588 Precision Time Protocol (PTP).

Increasingly, integrated time-synchronized operations are being deployed to improve the safety, flexibility, resiliency, and reliability of the electric supply. However, attacks on time synchronization equipment could potentially have adverse impacts on system operations. This project builds upon and extends the research developed in "Timing Security Assessment and Solutions" (SPN 3002008952) to investigate the downstream effects of time synchronization cyberattacks on power system applications. The project intends to develop recommended practices and reference architectures to address potential negative impacts to the operation of the systems that are downstream from GPS and other timing technologies included in the research scope.

This project will address the following research questions:

- What are the applications most sensitive to timing attacks?
- What are the mitigations found to reduce the potential for exploitation of vulnerabilities in power system and telecommunication applications?

This research intends to assess the direct relationship between cyber security gaps in current time synchronization technologies and the potential for cyber-attacks having a negative impact on power reliability. This research also intends to understand what set of practices and requirements could be adopted by the power industry including new technologies available in the market.

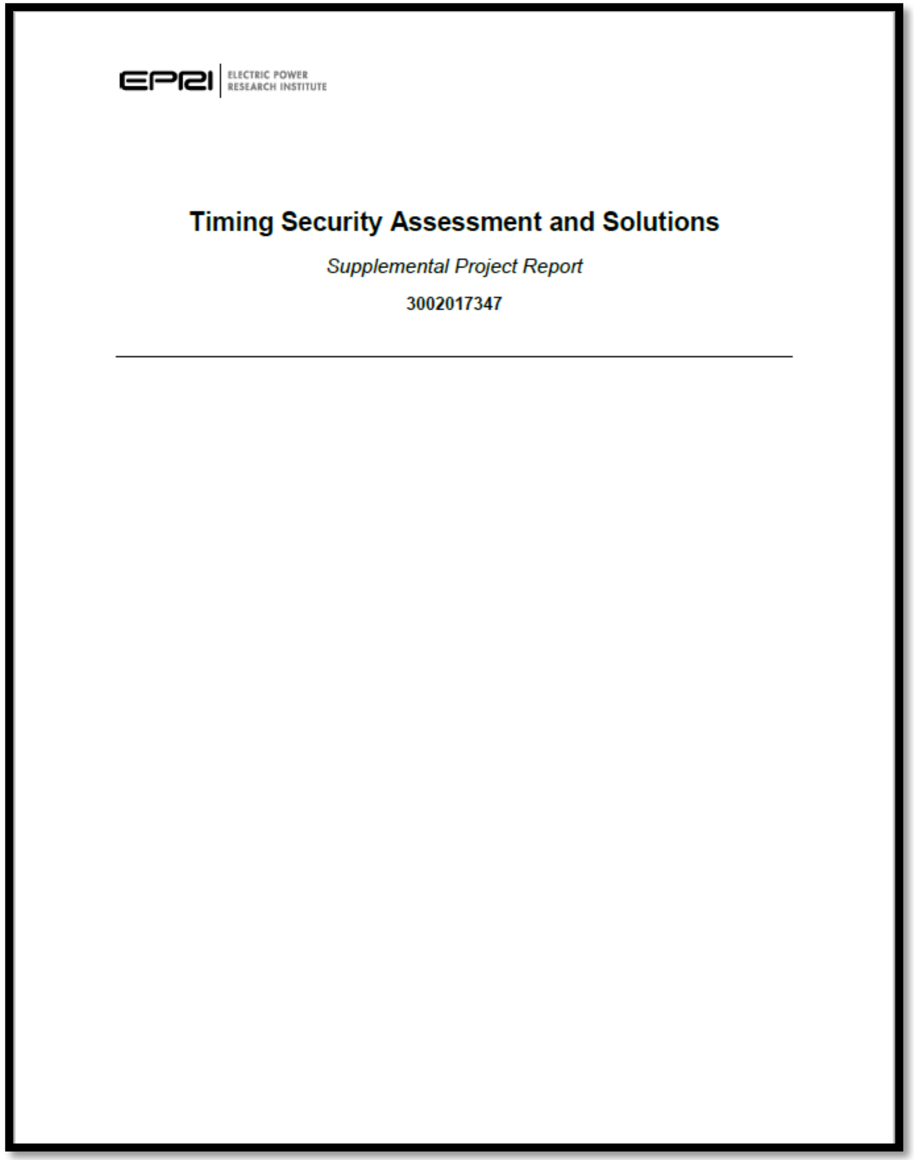
Benefits

Project participants will have increased understanding of the downstream risks and vulnerabilities inherent to timing synchronization equipment and applications. Utilities will have improved awareness of product vulnerabilities and future equipment security requirements for procurement purposes. Utilities will have improved awareness of new equipment that addresses previously identified vulnerabilities.

The public benefits from this project through improved security of time synchronization components of the electric grid that reduce vulnerabilities and the risk of malicious attack.

Timing Security Assessment Report

- Product ID: 3002017347
- **KEY FINDINGS**
  - Future systems that rely on time synchronization must be evaluated against attack vectors before deployment. This evaluation can occur in parallel to performance testing.
  - **LIMITED TO PROJECT FUNDERS**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Timing Security Assessment and Solutions

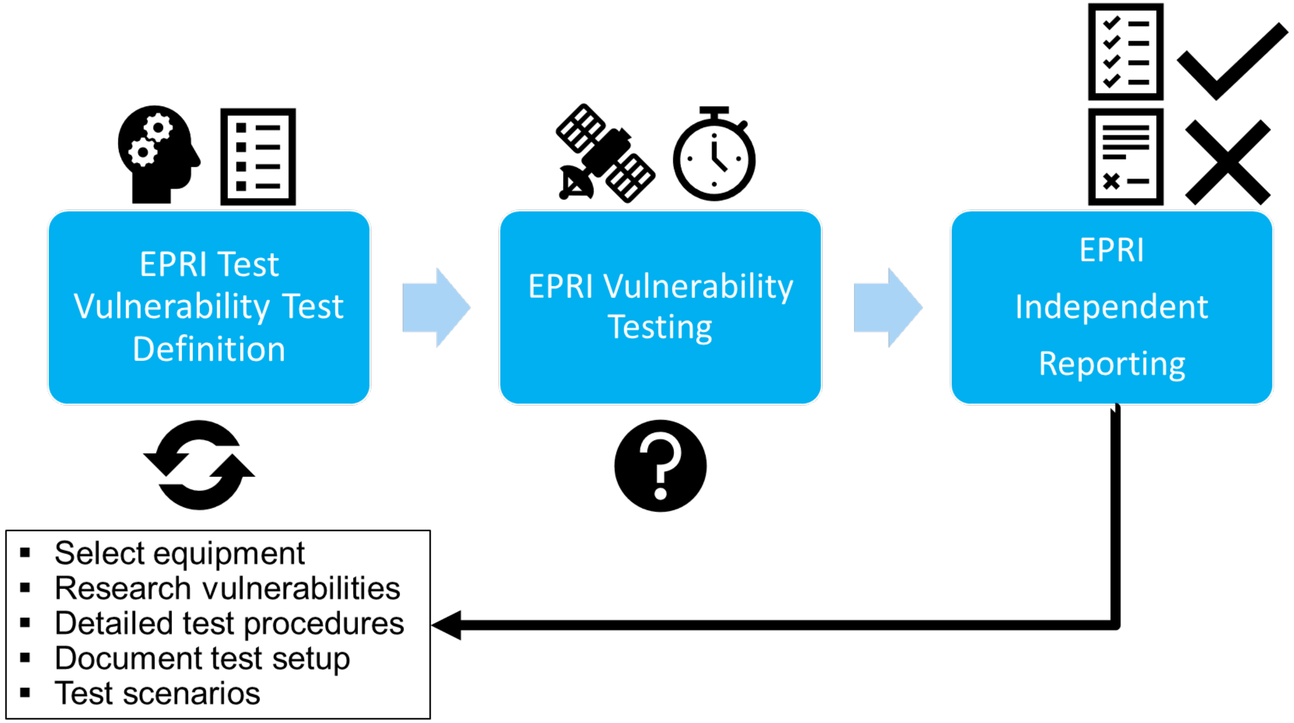
Supplemental Project Report

3002017347

Phase II Project Approach

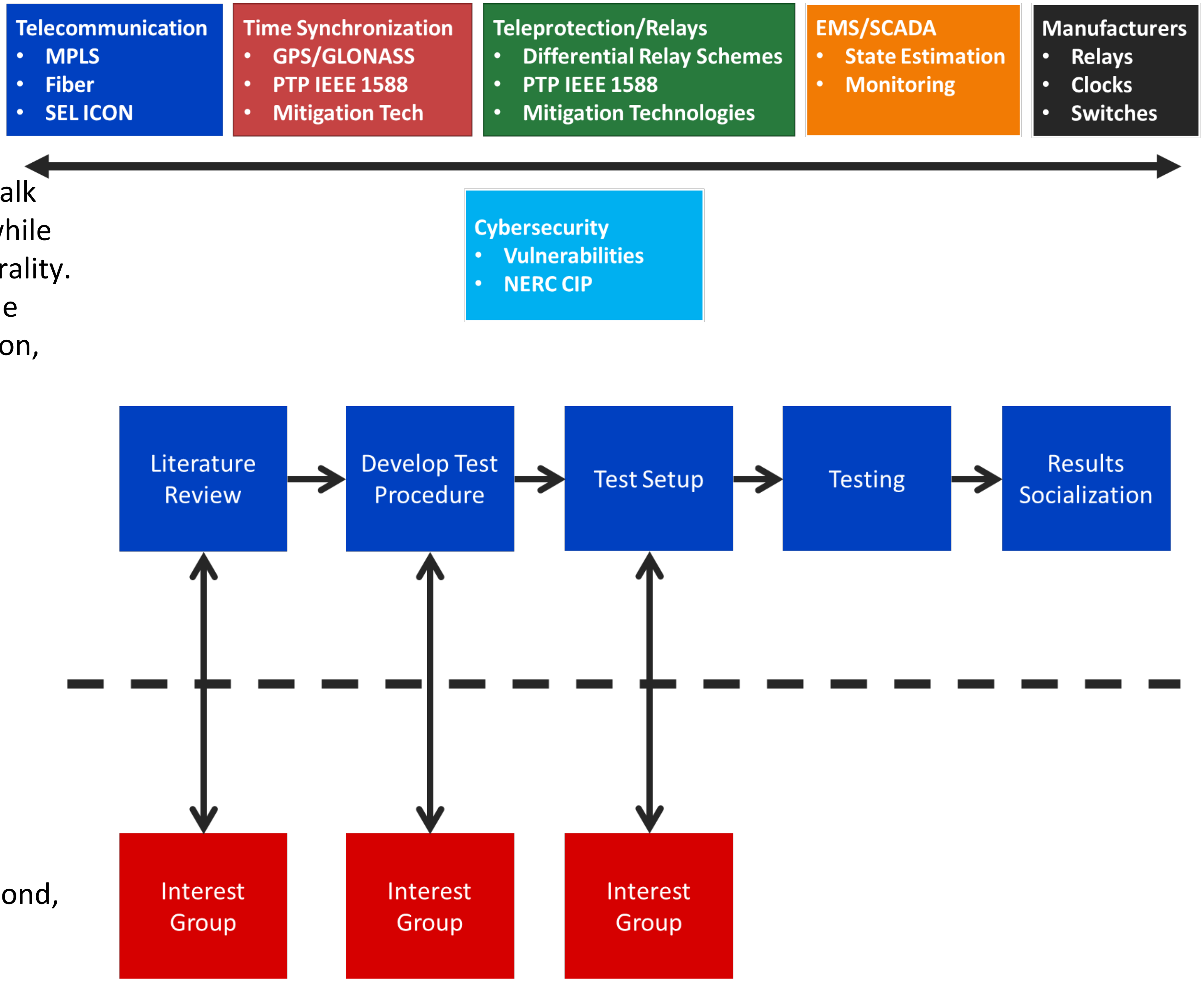
There are six (6) tasks planned for this project:

1. Review publicly available literature in relation to time synchronization vulnerabilities, technologies, and future states to help inform test plan development. Review will be summarized in the final report
2. Develop a test procedure document (to be included in report)
3. Implement a test setup in EPRI's Knoxville Cyber Security Laboratory or the project funder lab
4. Perform tests according to test procedure
5. Develop final report
6. Project management and socialization



Resilient Time Synchronization for the Energy Sector Interest Group

- **Objective**
  - Create a virtual forum for utilities to share experiences, talk about tools and techniques and explore research topics while maintaining impartiality, independence, and vendor neutrality. EPRI provides this forum without charge as a service to the industry and to promote the importance of reliable position, navigation and time (PNT) data in the energy sector.
- **Who Should Participate?**
  - Anyone who works with PNT or depends on PNT data
  - Utilities, vendors, governmental and industry groups
- **Structure of meetings**
  - Time: 1-hour total
    - One (1) Vendor/Academic presentation and Q&A
    - One (1) Industry Update and Q&A
    - Related announcements (i.e. issues, events, leap second, best practices events etc.)



Phase II - Tasks preliminary direction

Application Security Assessment

Approach
- Test plan development
- Threat Testing
- PTP and Telecommunication Technologies

New Technologies
- New Antennas
- External References
- Bump in the wire solutions
- Jamming/Spoofing
- Internal Clock
- Substation Anomaly Detection Monitoring

GPS Mitigation Evaluation

Resilient Timing

Substation Architecture Design and Evaluation

Next Steps

- EPRI intends to evaluate mitigation technologies and develop test plans according to technology approaches (i.e. antennas, GPS backup etc)
- EPRI intends to evaluate applications that may be impacted by time synchronization errors
- EPRI intends to test 2020-2021

Together…Shaping the Future of Electricity

Gerardo Trevino
Technical Leader
Cybersecurity

IP Broadcast Timing Requirements and Possible Solutions

Jaime Jaramillo
Senior Director Americas
ADVA Optical - OSA

Session 2: Timing in Finance, Electric Power and Broadcast
May 13, 2020

OSCILLOQUARTZ
An ADVA Company

70 YEARS
TIMING EXCELLENCE

SFP and integrated timing sources for Broadcast

Jaime Jaramillo

v.1.4

Agenda

- SMPTE 2010 & 2059 timing
- Providing sync to create, transmit & recover IP media content
- New innovative products to provide sync reference

SMPTE 2010 & 2059

Family of specifications created to make deployment & interop as easy as possible.

SMPTE ST 2110 -10 – Timing: SMPTE ST 2059 Parts 1 and 2

SMPTE ST 2110 -20 – Uncompressed video: IETF RFC 4175, VSF TR-03

SMPTE ST 2110 -21 – Video packet shaping

SMPTE ST 2110 -30 – PCM Digital audio: AES67

SMPTE ST 2110 – 40 – Ancillary data: SMPTE ST 291, RTP

SMPTE ST 2110 - 50 – Video: SMPTE 2022 part 6, VSF TR-04

Family of specifications created to make deployment & interop as easy as possible.

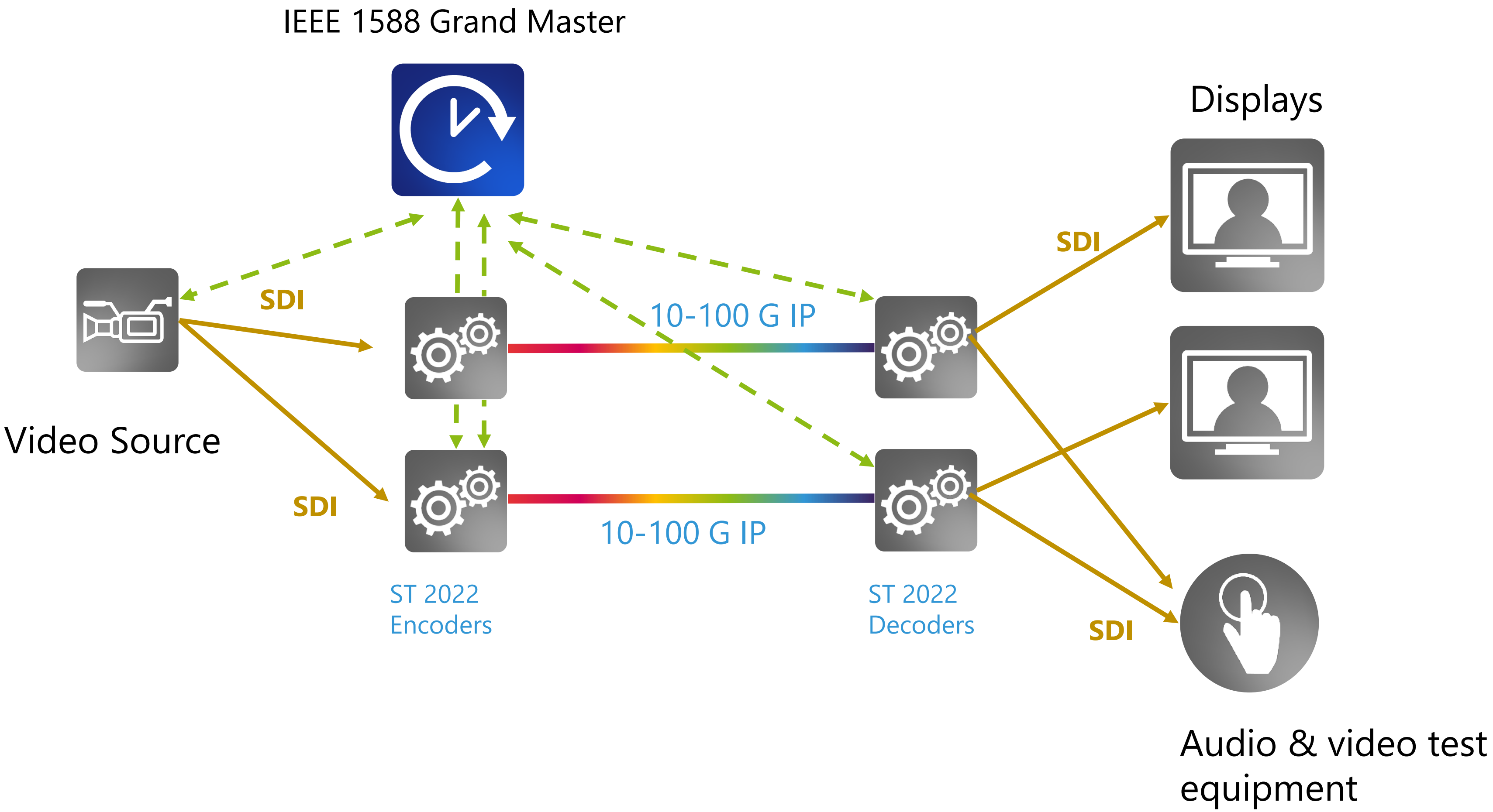
SMPTE 2059

- Utilizes PTP (IEEE 1588) to transport time reference signals (Time, frequency and phase) over IP for timing recovery in slave devices
- Allows for alignment of audio and video signals over IP links that are mostly asynchronous.
- Used for alignment of metadata as well in support of audio and video.
- Has a specific PTP Profile for media applications (SMPTE 2059 & AES 67)

SMPTE 2059 PTP profile parameters[4]

Parameter	Default	Minimum	Maximum
Domain number	127	0	127
Announce interval	250 ms	125 ms	1 s
Sync interval	125 ms	$\frac{1}{128}$ s	500 ms
Delay request interval	Sync interval	Sync interval	32 x Sync interval

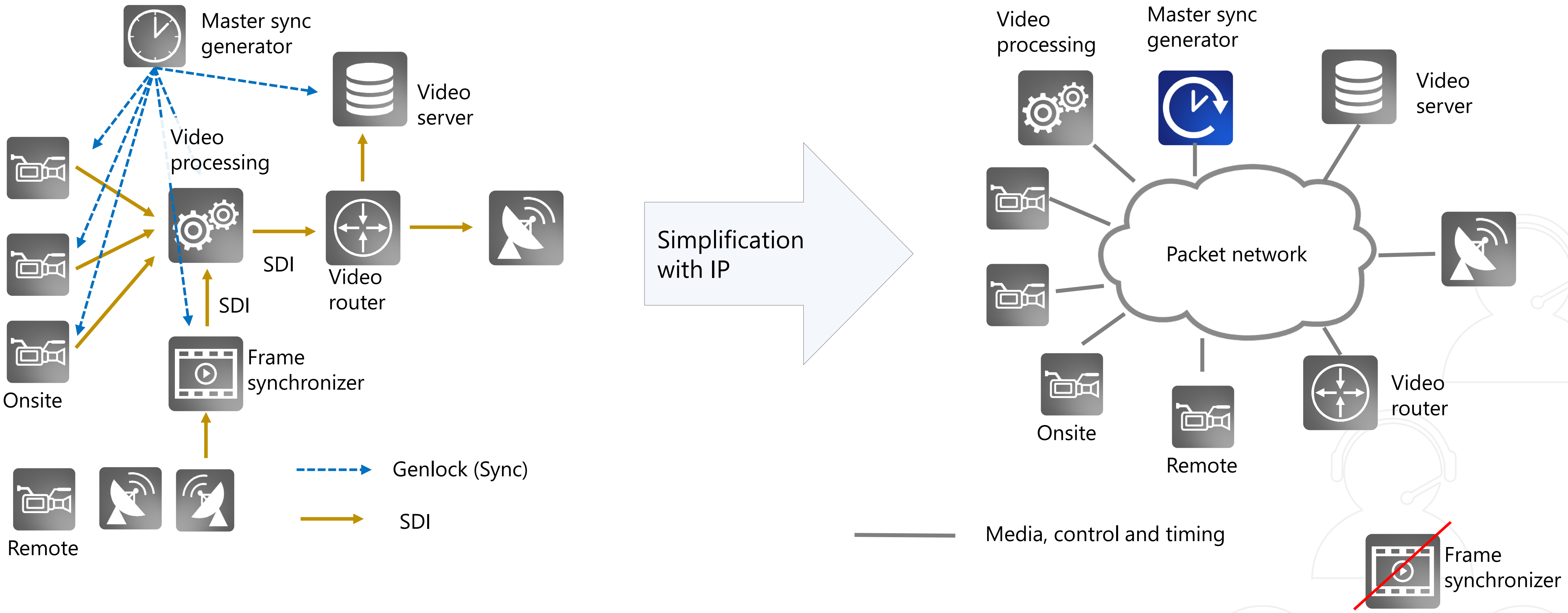
SMPTE 2059 typical application



Time Phase & Frequency sync of Tx and RX is critical for broadcast signal QoS over IP

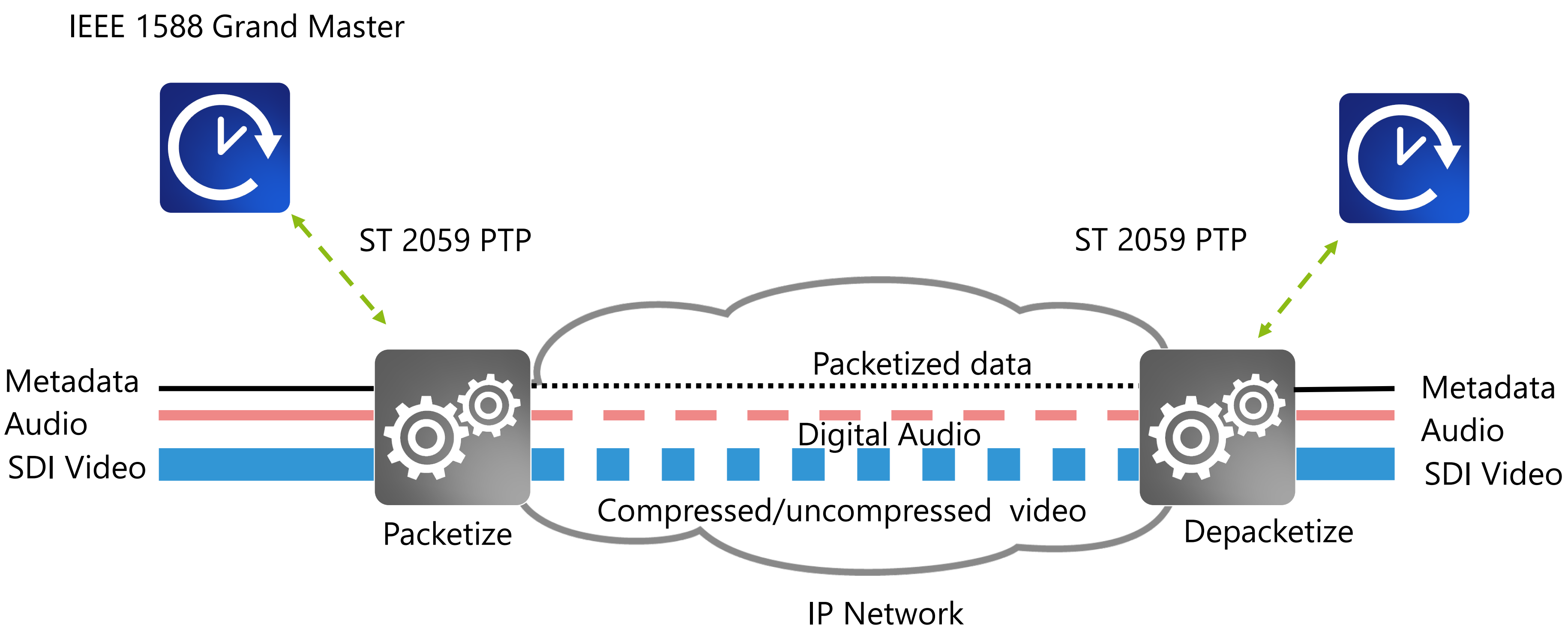
Using IP sync to create, transmit & recover content

PTP (SMPTE 2059) replaces SPG



SMPTE 2059 uses PTP IP packets to do the job traditional SPGs do:

Lip Sync

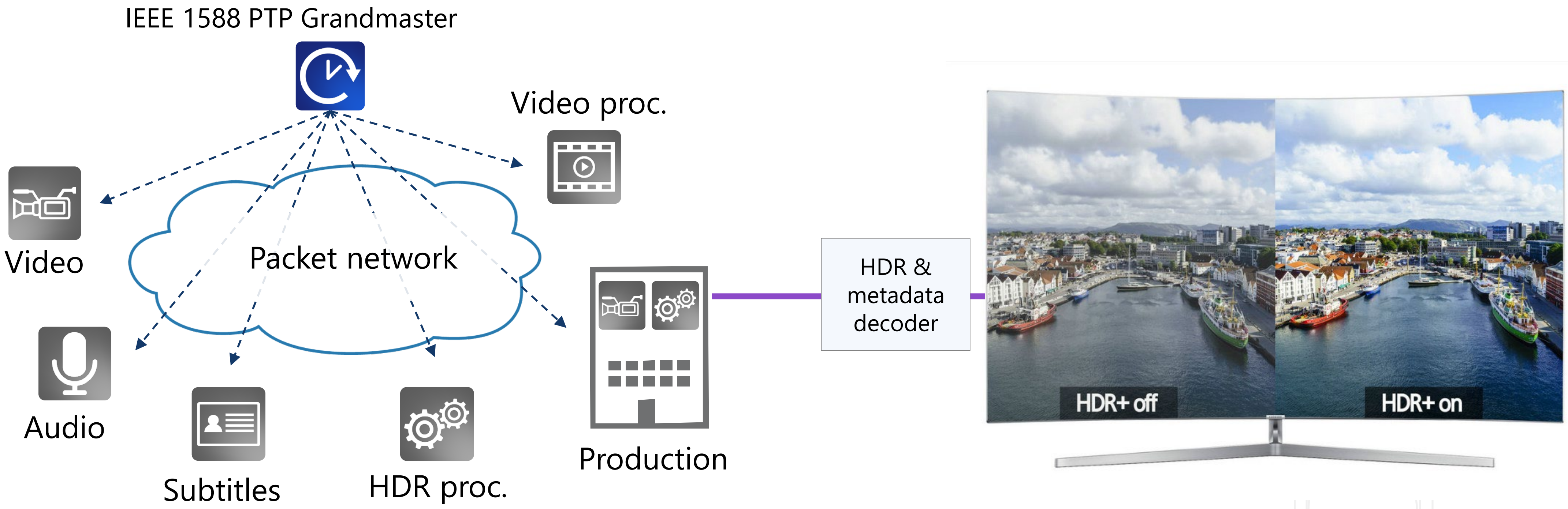


Audio, video and metadata packets must be timestamped so they can travel over a switched IP infrastructure.

These packets are then recovered and realigned with their respective audio, video and metadata packets so as to not introduce impairments to the recovered output.

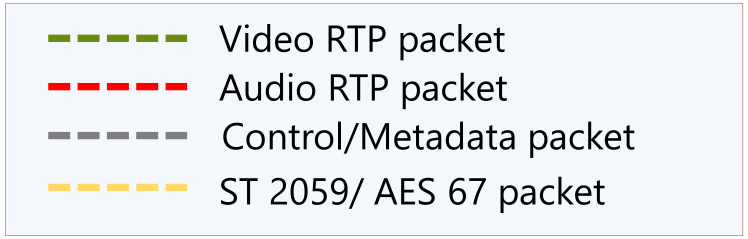
Broadcast signals get "packetized" and sent over IP which does not necessarily guarantee arrival order or quality. Timing aligns packets at the receiving end for optimal QoS

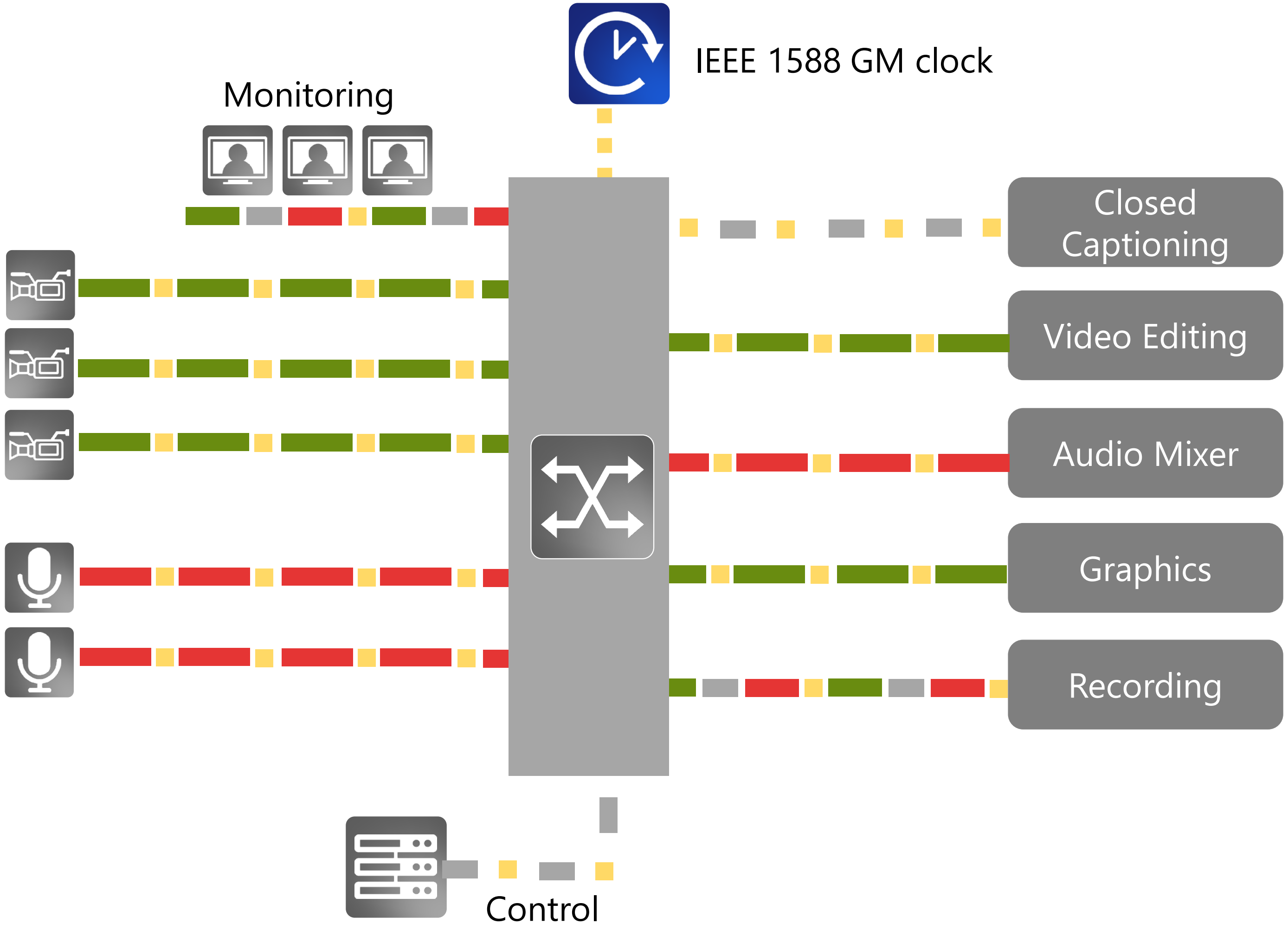
Frame accurate metadata



When metadata is timestamped in alignment with audio and video, impairments are minimized at end device (decoder).

IP workflows



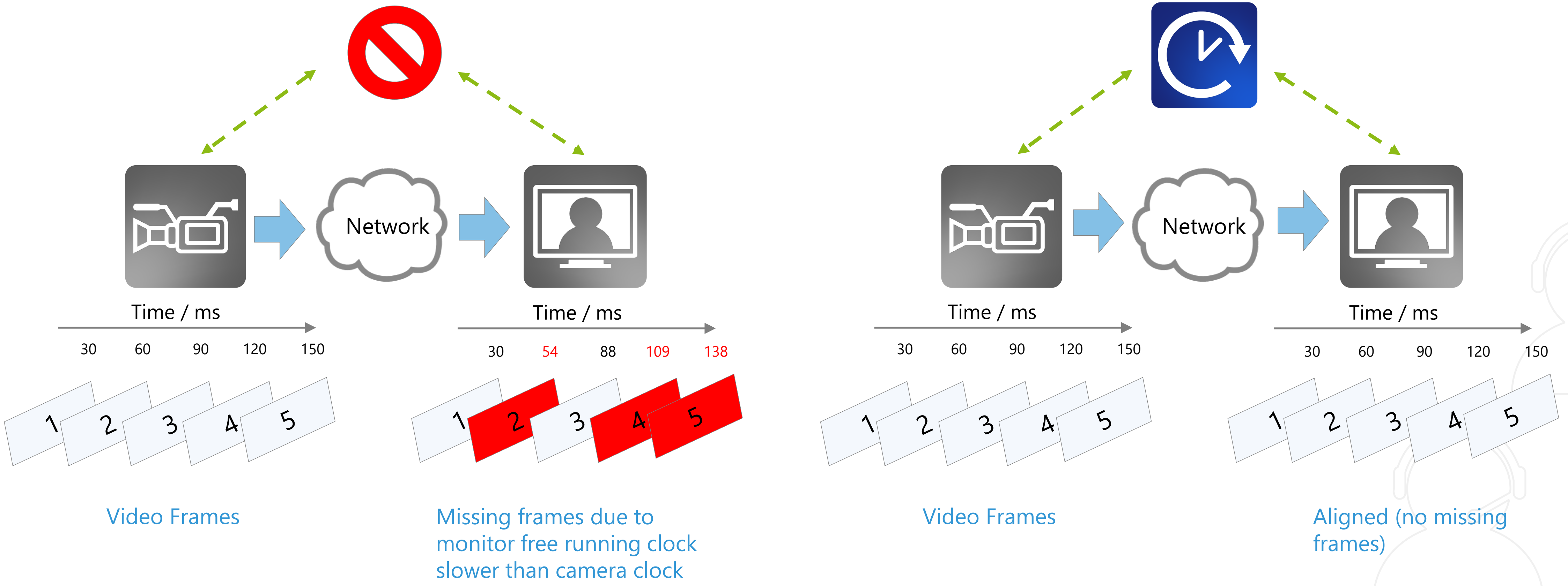


Given high accuracy timestamping of audio and video, additional information (Metadata) such as subtitles and languages can more easily be added to content streams.

Editing & production also is facilitated given all video and audio can be synchronized at the production facility now that all content at the packet level is timestamped with SMTPE 2059 and/or AES 67.

Given all content is packetized and synchronized, production now can happen anywhere

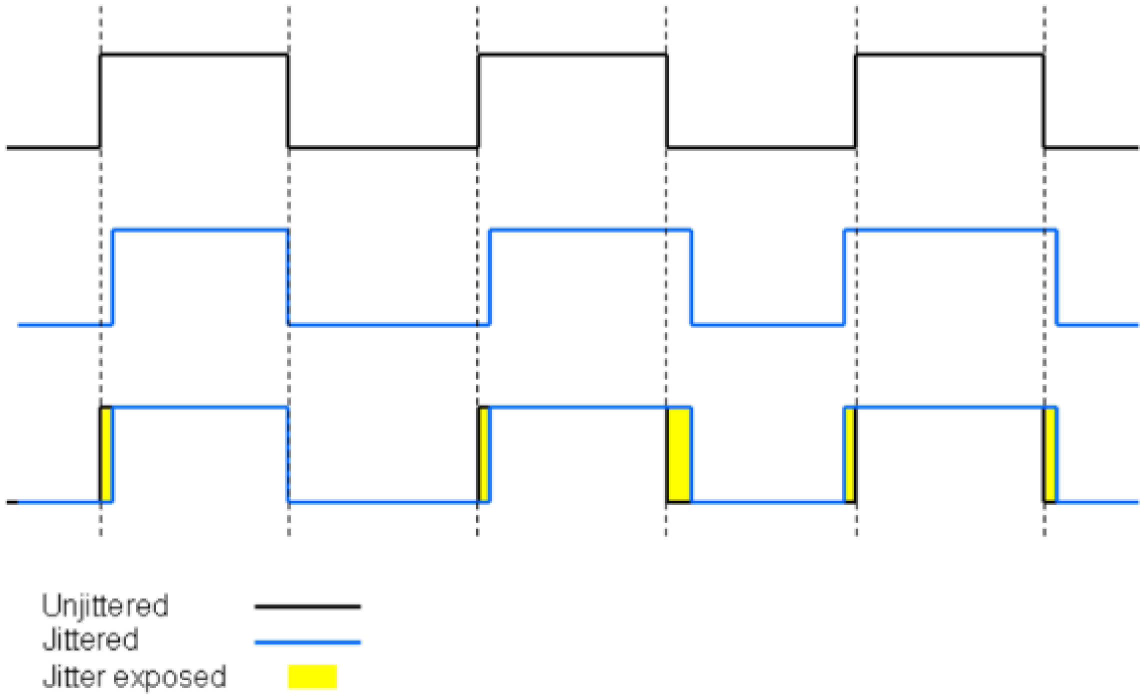
Unlocked oscillators cause instability

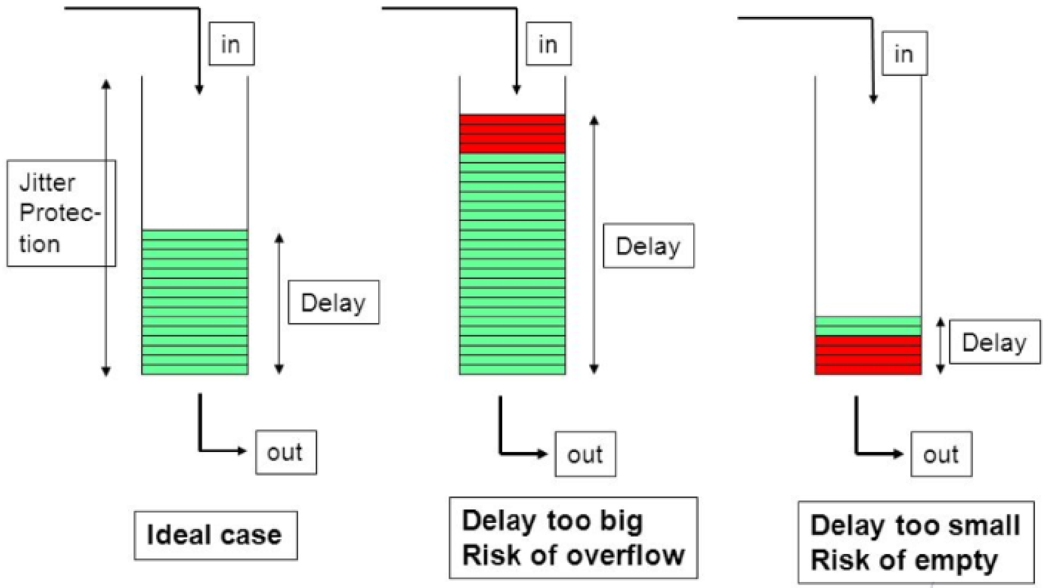


Device clocks drive processing & Tx speed. All frames sent are received & processed in order and on time when device clocks are in alignment.

Jitter is the enemy

If Tx clock phase varies (jitter) past application spec, then signal quality is affected.

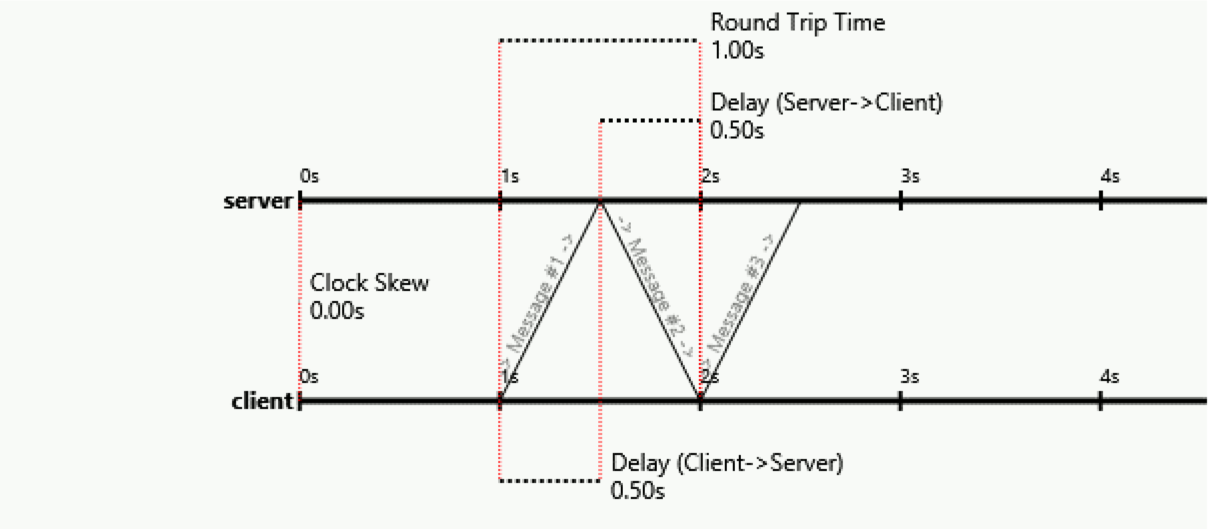




Solution is to have the Tx and Rx devices referenced to a common source within accuracy specs to assure jitter buffers are maintained within ideal case.

Networks must have low PDV

Device internal oscillator



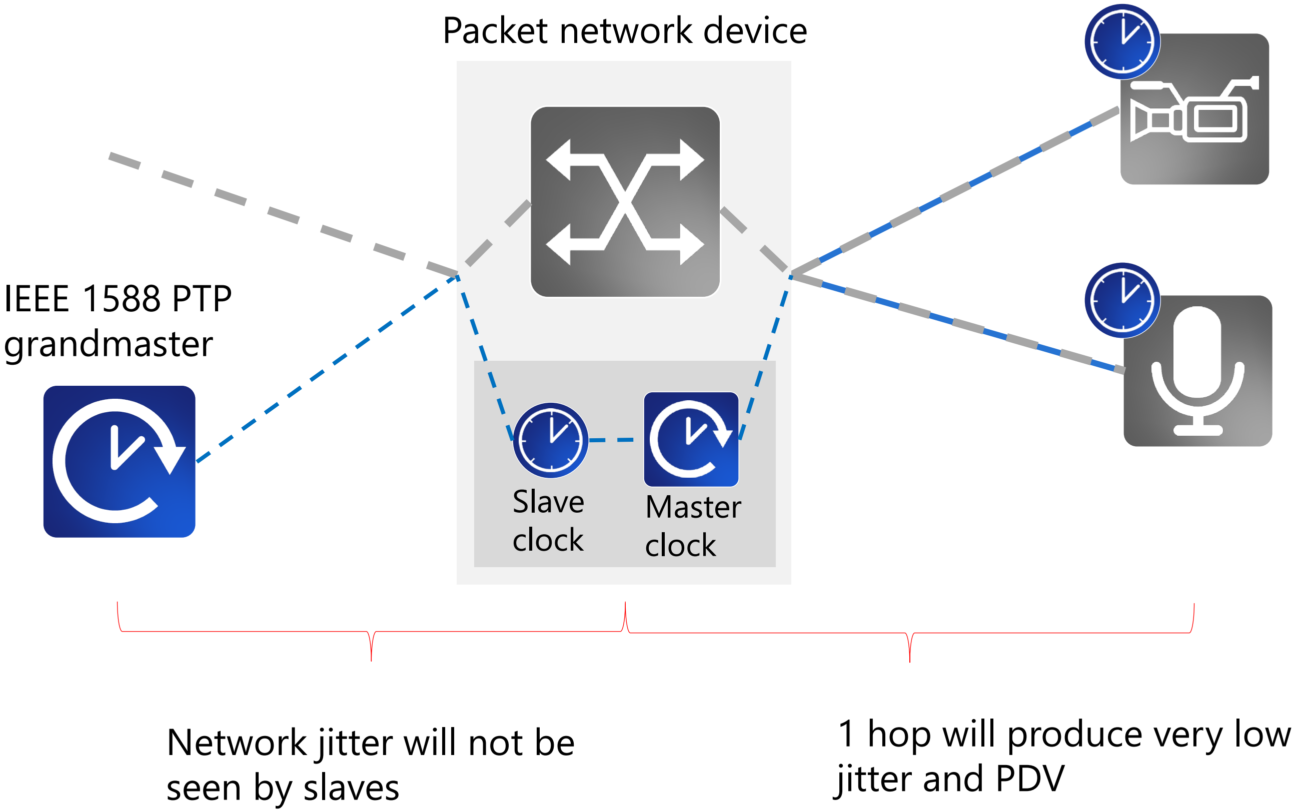
Packet delay variation is what most affects packet recovery within QoS specs.

If the time it takes packets to go from the Tx to the Rx (server to client) varies constantly, then the timing recovery algorithm can not recover a stable frequency or phase reverence, which impacts audio and videos QoS.

Ensuring network elements implement packet prioritization technologies and use common timing references to ensure buffers work at idea levels is critical. (use presentation mode)

Network elements as well as devices that create and recover audio and video must have high accuracy time, phase and frequency references or QoS is impacted.

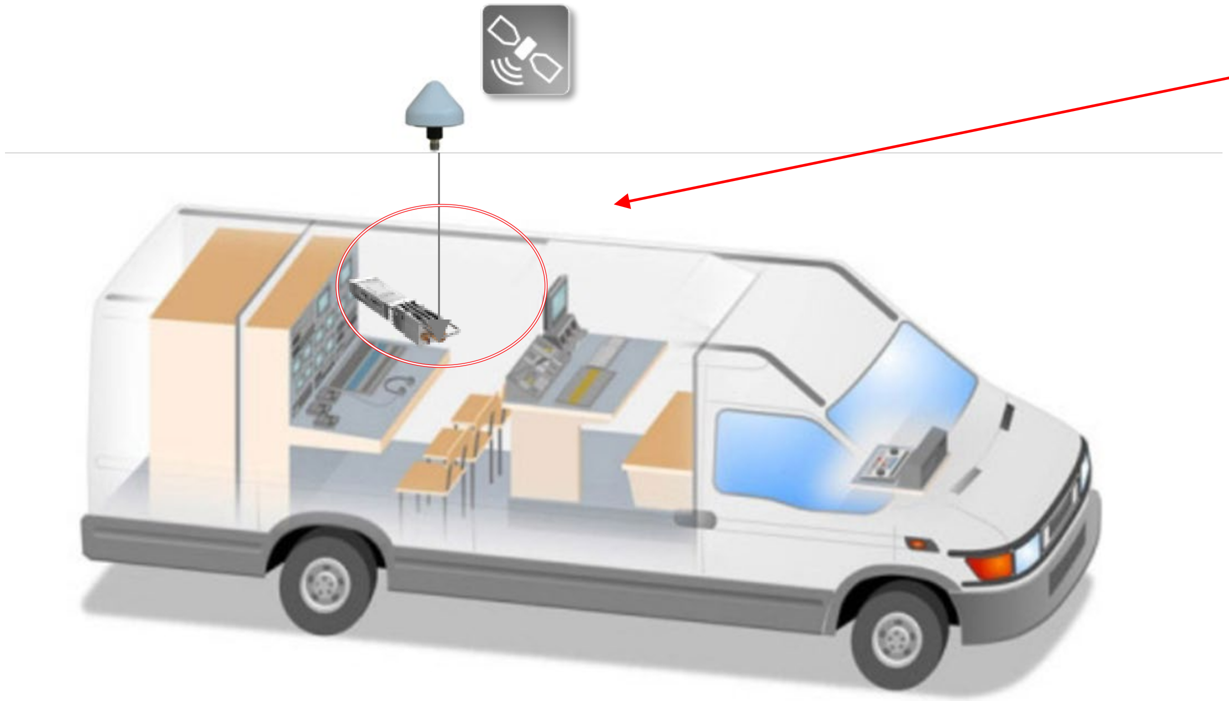
Boundary clocks keep jitter low



PTP slaves (devices taking time reference from a master clock) or in this case a boundary clock, are not impacted by the upstream network QoS to the BC. This though only applies to all the slaves (devices) using the same BC as a timing reference.

This is how BCs eliminate most jitter due to network PDV.

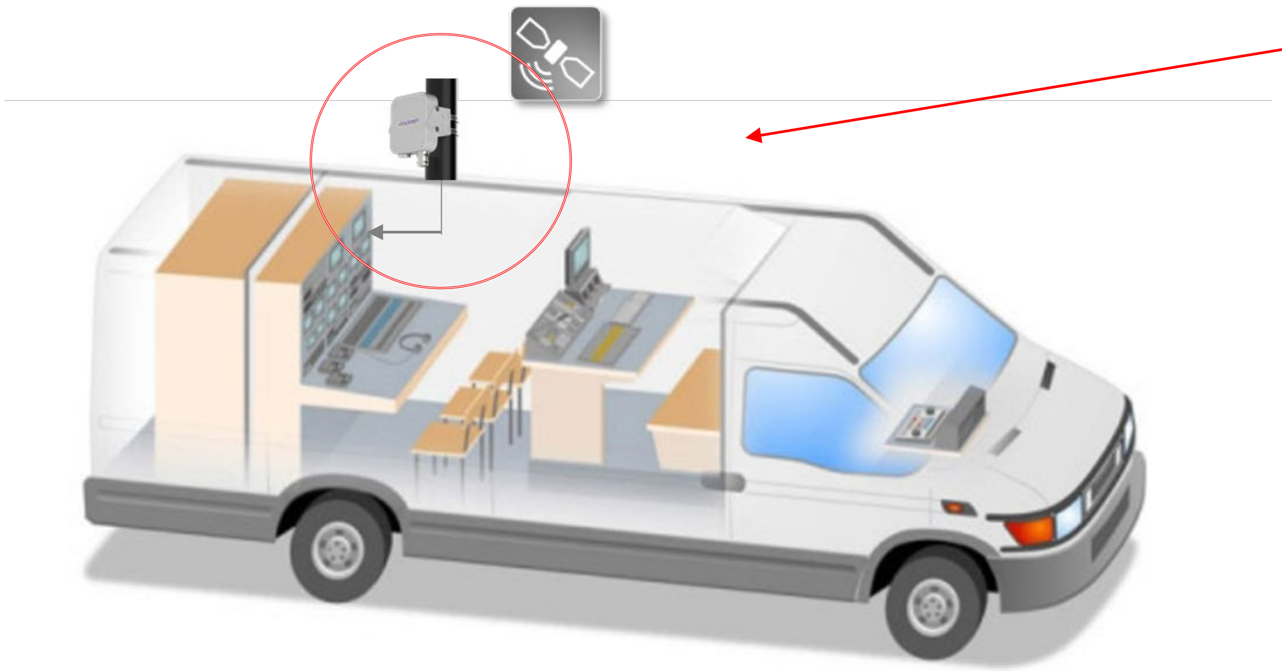
An SFP based GM clock provides an easy solution



- A Master clock source can be added to a mobile unit easily to provide timing to all equipment used to capture audio and video in the field.
- Zero footprint: no additional physical space required.
- Leverages host equipment.
- Small size = low price
- Low price = can be deployed in many mobile locations.
- Enables 2110 in mobile units.

SFP based master clock is easy to easy to install, low weight and low cost!

Benefits of using a GM clock with integrated antennas



- Integrated antenna makes installation extremely simple.
- Small size – can be installed inside or on outside of mobile units.
- Low cost enables 2110 in just about any scenario.
- Clock source can be up and running in minutes.

Integrated master clock only requires ethernet connection and PoE. No antenna cable or antenna required.

Summary

- Next generation broadcast applications are moving to IP to take advantage of lower cost and flexibility offered by IP technology.
- As video content increases in resolution, more streams & packets are created to be transmitted over limited bandwidth connections.
- Audio is also streamed with metadata and these streams must align with video when transmitted over asynchronous IP network connections.
- Networks & paths must be engineered to introduce as little packet delay variation (Jitter) as possible to ensure highest QoS.
- Timestamping all the various audio and video packets is critical to re construct HQ streams for end users.
- Low cost, highly flexible time sources must be deployed so that all content created in IP, can be produced, edited and transmitted with high resolution content with expected QoS.
- IP networks for broadcast must deliver content streams with highest QoS possible to avoid impairments and low QoE.

IP delivers higher flexibility for broadcast services but timestamping and network engineering are critical for meeting expected QoS.

Thank you

Jaime Jaramillo
jjaramillo@adva.com

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Enterprise Computing Time Synchronization Update

Steve Guendert
IBM Z Timing Hardware Systems Architect
IBM

Sponsored by: Calnex

Session 2: Timing in Finance, Electric Power and Broadcast
May 13, 2020

IBM Z

Enterprise Computing and Time Synchronization Update

WSTS 2020

13 May 2020

Steve Guendert, Ph.D.

IBM Z Timing Architect

Member, IBM Academy of Technology

Steve.guendert@ibm.com

Abstract

The latest generation of IBM Z Systems family of mainframes is used by over 90% of the worlds 100 largest global banks as the computing platform they run their businesses on. The IBM Z also is heavily used in other financial, insurance, and retail companies worldwide to the point where it is often said that the world's economy runs on IBM mainframes. This session will discuss the time synchronization regulatory changes that led to IBM studying the IEEE 1588 Precision Time Protocol (PTP), and what IBM is doing with PTP and these enterprise computing platforms that are central to the world's financial systems. We will also discuss some of the ideas IBM has on highly resilient time synchronization networks to improve availability and security of this mission critical cyber infrastructure.

Agenda

- Intro
- Latest financial industry time synchronization regulations
- IBM Z time synchronization today
- IBM Z and PTP
- IBM Z time synchronization direction
- Thoughts on resiliency

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Time Synch Recent Regulatory Changes: Background

- Widespread proliferation and usage of electronic trading platforms with their automation
- Advent of High Frequency Trading (HFT)
- Increased the need for tighter synchronization and traceability to a common reference time scale
- All systems playing a role subject to the new rules

Government Regulations-US (FINRA)

- **Effective 2018 , requires synchronization of equipment to within 50ms of NIST(UTC)**
  - Also requires audit log capability to prove compliance
- Consolidated Audit Trail (CAT)
  - Requires sending of complete documentation on all orders to a central repository by 8am Eastern Time the day following a trade.
  - Requires time stamps at **ms resolution** at five places in the audit trail

FINRA CAT February 2020 Update

- IBM made aware by clients that this is starting to be enforced this summer

Standard: The Industry Member would need to self-report a deviation if a system creating and recording CAT Reportable Events drifts out of compliance with the established standards **10 times in one rolling 24-hour period** at any time when the system is recording a timestamp on data that is reportable to the CAT on a given device or server. (The 10 times standard also applies to systems that process Manual Order events.)

FINRA CAT™

CAT Alert – **2020-02**, Updated Publish Date: 02/25/2020

STANDARDS FOR SELF REPORTING DEVIATIONS OF CLOCK SYNCHRONIZATION STANDARDS TO FINRA CAT

1. SUMMARY

On January 28, 2020, the CAT NMS Plan Operating Committee approved parameters for when a CAT Reporter is required to self-report to the CAT Plan Processor, FINRA CAT, deviations of clock synchronizations standards required under SRO Rules and the CAT NMS Plan. FINRA CAT will use this information to evaluate the impact of the reported incident(s) on the quality of the CAT Data and to provide notice to the Regulatory Users of reported incident(s) that may impact their analysis of CAT Data.[1] This alert provides information regarding the current clock synchronization standards, the

Government Regulations-EU (ESMA and MiFID II)

- MiFID II requirements went into effect in January 2018
- MiFID II applies to any organization dealing in European financial instruments
- MiFID II clock synchronization requirements are more stringent that the latest U.S. requirements previously discussed
- Business clocks that provide the timestamp for any reportable event should be coordinated to UTC, using either a link to one of the laboratories maintaining a UTC(*k*) realization of UTC, or the time signals disseminated by GPS or other satellite system.
- Level of accuracy number typically cited: 100 microseconds divergence from UTC
  - 1 microsecond or better timestamp granularity

Server Time Protocol (STP) : 2006-today

- Designed to provide the capability for multiple servers to maintain time synchronization with each other and form a Coordinated Timing Network (CTN)
  - CTN: a collection of servers that are time synchronized to a time value called Coordinated Server Time (CST)
  - Single view of time with an external time reference
- Message based time synchronization protocol
  - Similar to Network Time Protocol (NTP)
  - Timekeeping information transmitted over specialized connections (coupling links)
  - Supports a multi-site timing network of up to 200 km over fiber optic cabling
- Two external time source options (prior to May 2020)
  - NTP server (100ms accuracy)
  - NTP server with Pulse Per Second (PPS) (10 us accuracy)
- STP will maintain all of the systems in the Coordinated Time Network (CTN) so that their timestamps stay within less than **10 μs** **of each other**

Emergence of Precision Time Protocol (PTP)

A higher precision protocol….

- Transmission times measured with hardware assistance
- All switches and devices participate
- Capable of synchronization into the sub-microsecond range
- Currently used primarily in telecom and utility industry, moving into finance

IBM Z is moving forward and integrating PTP into IBM’s Server Time Protocol (STP) environment

- Improved synchronization between mainframes
- Better synchronization to UTC
- Better synchronization to non IBM Z equipment
- Provide greater resilience of the STP CTN

Recent IBM Z 15 Announcements

- 12 Sept 2019 IBM Announcement letter
  - New IBM mainframe announced
  - Formally announced our statement of direction for IEEE 1588 Precision Time Protocol (PTP)
  - The regulatory changes previously discussed were the primary driver
- 14 April 2020 IBM Announcement letter
  - Support for PTP announced
  - General availability (GA) 15 May 2020
  - The initial implementation will be for PTP connectivity via the IBM Z HMC/SE Hardware Management Console/Support Element
  - At that time there will be no change to the use of STP CTNs for time coordination, other than the potential to use a PTP-based external time source.

Statement of General Direction for PTP

- Future implementation is planned to include full connectivity of an external PTP time source directly to the IBM Z central processing complex (CPC).
    - Reintroduces the concept of a mixed CTN
    - Support for traditional STP
    - Support for native PTP implementations
- Beyond this, the goal is to enhance the role of IBM Z machines in a PTP environment that addresses the many governmental regulations and security concerns that our clients are facing.

Thoughts on Improving Time Synchronization Network Resiliency

- Discussions on resiliency are about the triad of high availability, redundancy, and security
- The Global Positioning System is not about position, its about time
  - Need to have a backup plan
  - What are you going to do?
- Network security vulnerabilities due to network design, poor habits, or protocol vulnerabilities
  - NTP has well publicized/well documented security issues
    - New NTS for NTP Draft RFC in the IETF
- Dedicated network for time synchronization?

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Thoughts on Improving Time Synchronization Network Resiliency

- Time synchronization information is not a secret-it does not need to be encrypted
  - However, some end users require all networks to be encrypted
- Robust authentication must be used
- PTP standard’s security annex should not be considered “optional”
- Accuracy is important, but not the be all end all
- Standards need to incorporate resiliency (security). The argument that its incorporation hurts performance may be valid, but not valid enough to exclude

If you don’t have enough resiliency, and something bad happens, is anyone going to care about what kind of performance you <u>had</u>

Summary

- Background on the modern IBM mainframe and use cases
- Discussed the recent financial industry regulatory changes that drove IBM to support PTP on the IBM Z (mainframe)
- Discussed IBM Z time synch, and Server Time Protocol (STP)
- Discussed IBM Z PTP announcement and statement of direction
- Discussed some thoughts on time synch network resiliency

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QUESTIONS: Submit using the questions tab on the control panel located on the right side of your screen.

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Pat Diamond
Diamond Consulting

Victor Yodaiken
FSMLabs

Sarath Madakasira
Microsoft

Keith Mange
Microsoft

Tommy Cook
Calnex

Jeff Dagle
Pacific Northwest National Laboratory

Gerardo Trevino
Electric Power Research Institute

Jaime Jaramillo
ADVA OS

Steve Guendert
IBM

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

The Insights Continue:

Session 3: **Timing Security, Resilience and GNSS Issues**

Wednesday, May 20

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