UCA IEC61850 Interop Time Synchronization Testing Takeaways & Conclusions

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WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Agenda

- What Is The UCA?
- What Is IEC61850?
- What Is The UCA IEC61850 Interop?
- What Do You Do When You Can’t Get A GNSS Signal Into The Venue?
- Some Test Cases
- What Did We Learn?

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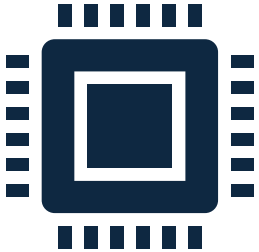
What Is The UCA

- UCA Stands for Utility Communications Architecture
- Today's IEC61850 Standard has its roots in the UCA
- The UCA International Users Group (IUG) hosts the UCA Interop Event, which was held last year in August in Birmingham, AL
- To learn more about UCAIUG, visit their website: https://www.ucaiug.org/default.aspx

Information Source: Herb Falk, IEC 61850 Demystified (2019), Chapter 2

What Is IEC 61850?



An Engineering Toolset for Digital Substations

- Defines Data Models for Devices
- Designed Information Flow
- Reduces Customization To Promote Interoperability of Components Designed by Multiple Vendors
- The Types of Messages And Protocols By Which To Communicate Over (GOOSE, SV, MMS, for example).
- Data Storage of Configured Data via SCL

In Terms of Timing it Defines

- Defines the use of IEC 61588 (PTP)
- Defines the use of IEC 61850-9-3 Utility Profile
- Communication Protocols
    - For Clocks: MMS
- The Data Model/Variable Definition for Properties Imported/Exported into/from a clock

What Is The UCA IEC61850 Interop

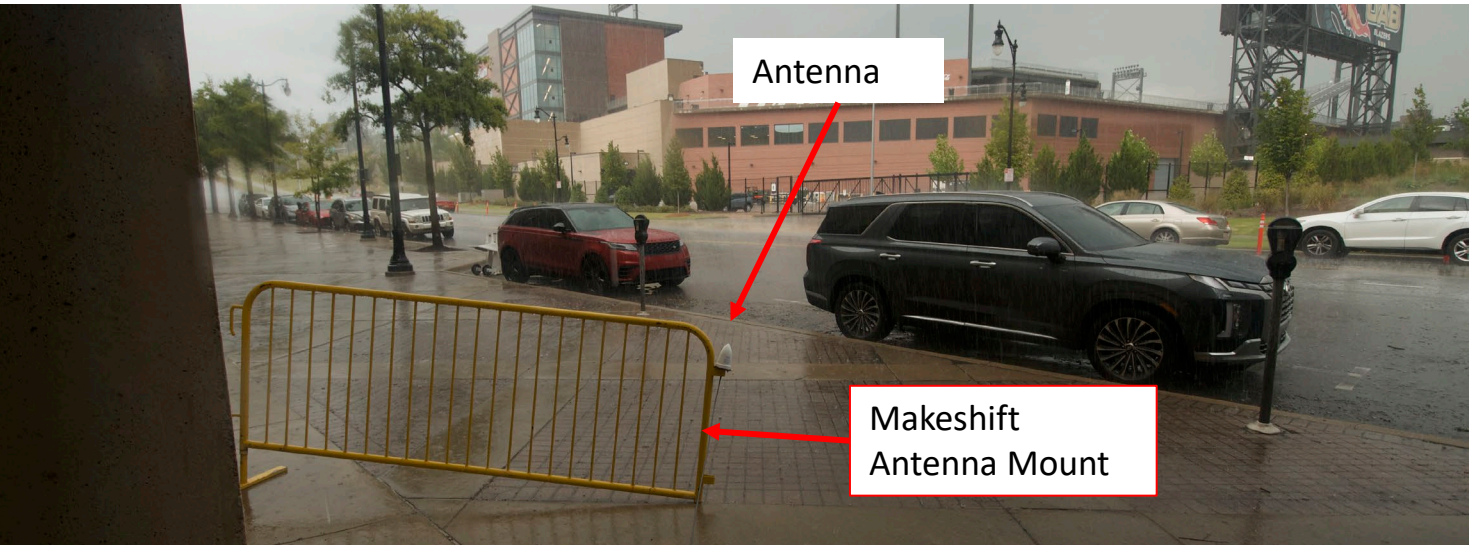
- Goals
  - Simulate protection schemes and in relation to various aspects of IEC61850, including time synchronization and protocol testing
  - Test interoperability between various vendor hardware
  - Herb Falk: “This is where everyone comes to fail”
- Dozens of Vendors Participate
  - Effort of 10+ Vendors Participating in Time Synchronization Tests
  - Utilities Attend To Witness Tests

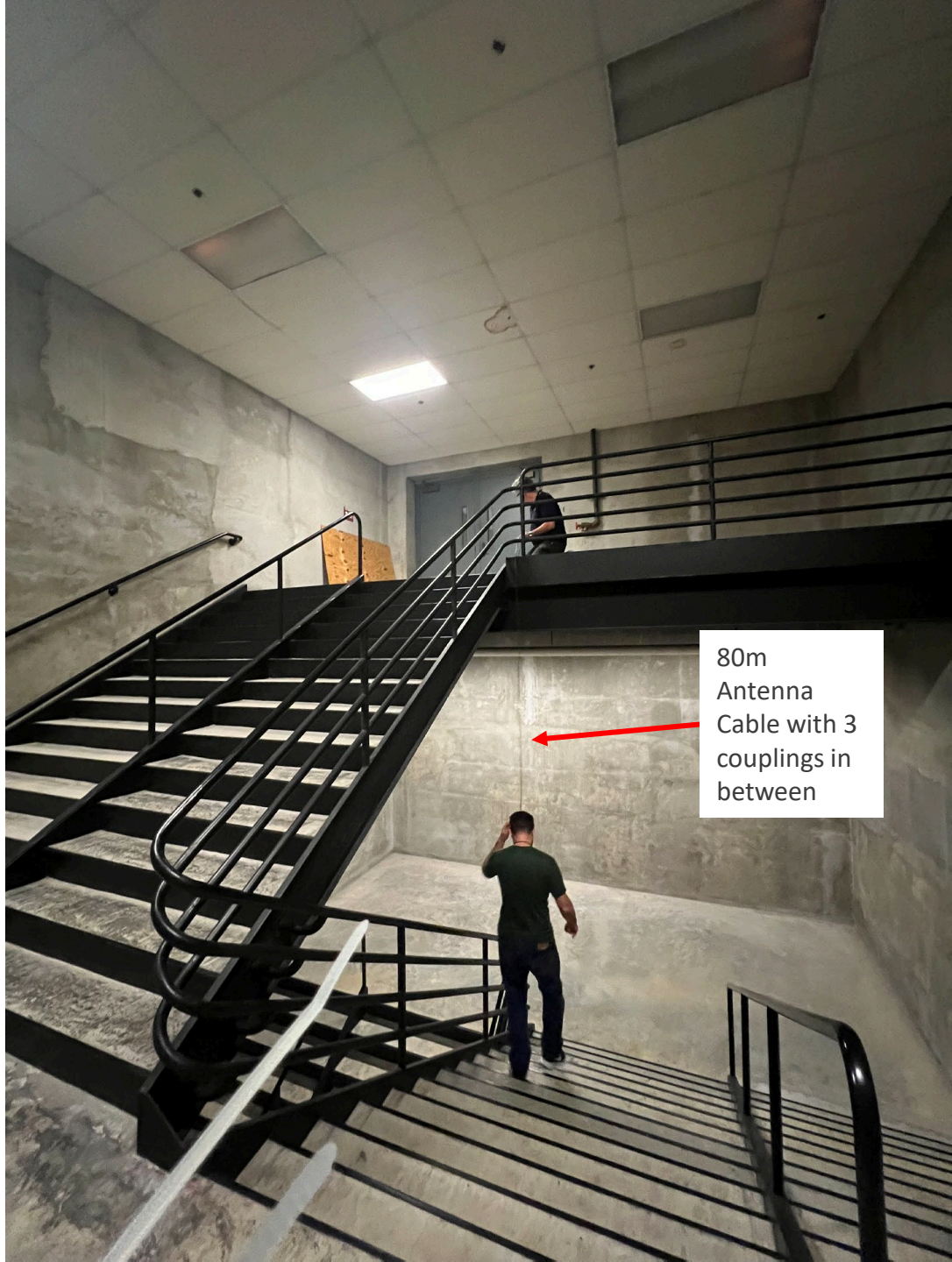
Where Did We Fit In

- We Volunteered To Create Time Synchronization Tests in Collaboration with Other Participants
- Time Synchronization Test Cases
  - Testing How Protection Functions like 87L (Line Differential Protection) Respond To A Time Jump of Varying Magnitudes
  - Multiple Domain Tests for Transparent Clocks
  - Holdover Performance Tests
  - Failover In Holdover
  - Failover During Slewing
  - Spoofing Test (Single band, GPS/GLONASS Constellations)
  - Failover to Alternate Reference Source Testing
  - PTP Profile Tests & BMCA Testing

Testing Setup: What Do You Do When You Are Told You Can't Get A GNSS Signal Into The Venue?

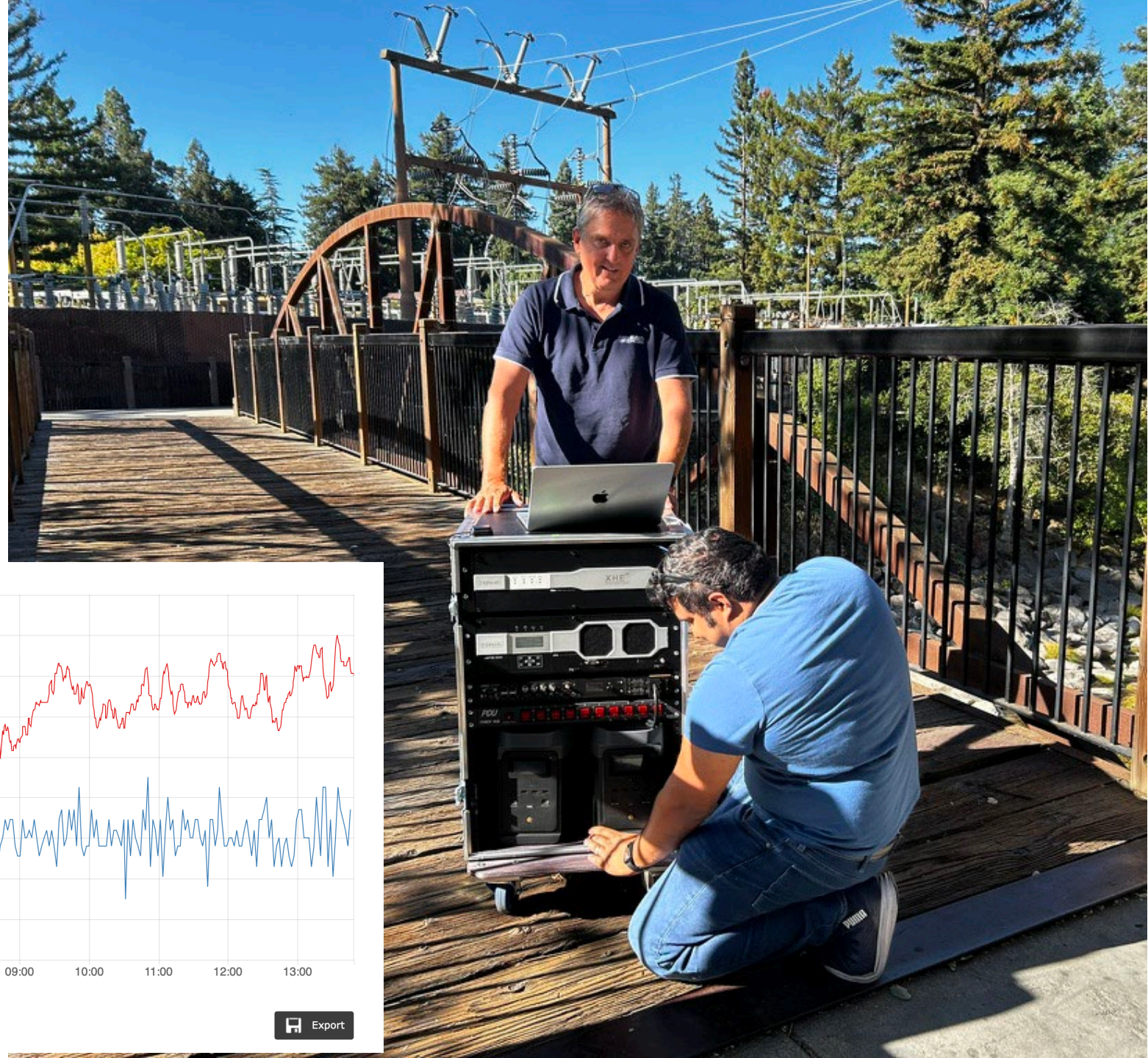
- Try To Run A Very Long Cable for an Antenna for a Clock
  - One of the GNSS antenna splitters used to connect clocks under test was ultimately found to be faulty
- Use a GNSS Simulator with a frequency reference
  - Build an Atomic Clock On Wheels for the frequency reference
    - Synchronize The Clock To GNSS In A Hotel Room for 24h
    - Wheel it In
    - Hope It Works (Hint: It Does)

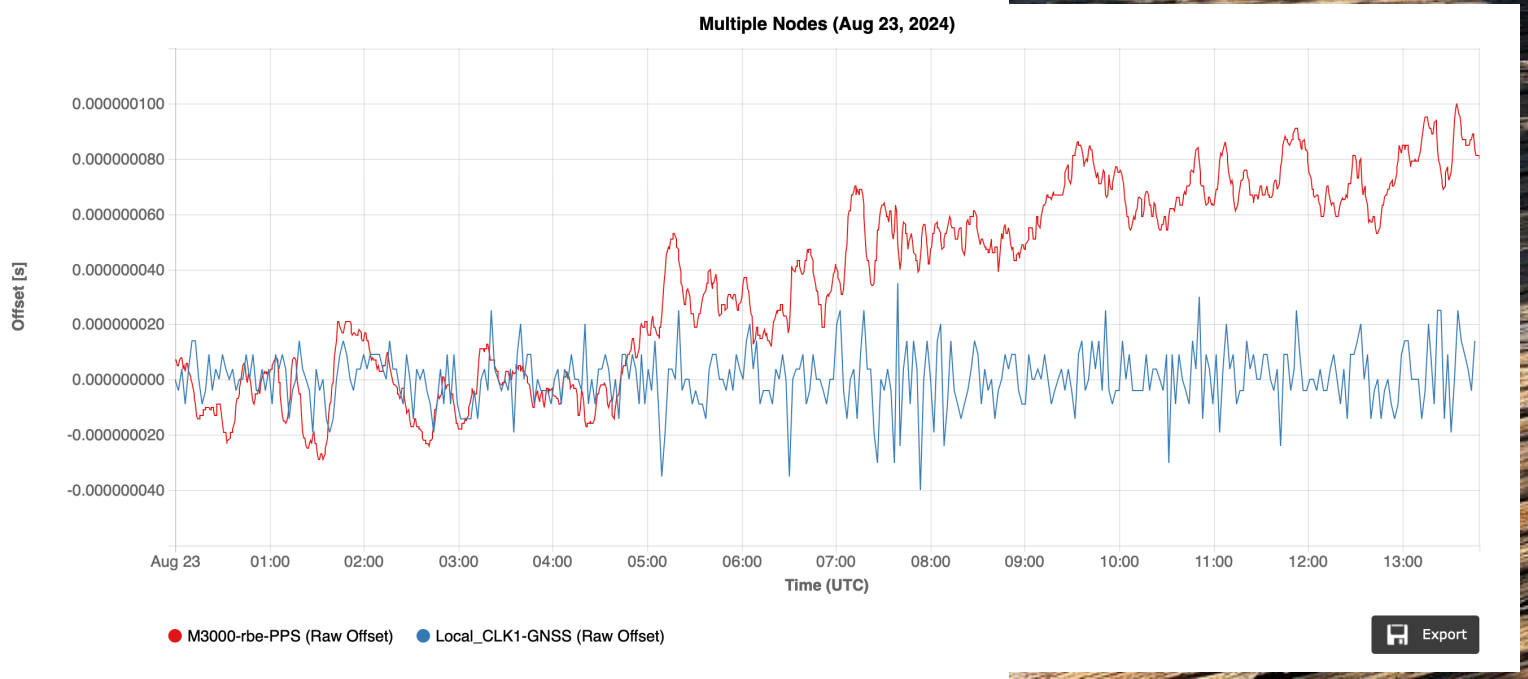




The Frequency Reference

- Test It Prior to Arriving
  - Tested Rb prior to moving it: approx. 80ns drift in approx. 12 hours
  - Rolled it around outside for 10-15 minutes to see what that would do: no discernable effect on stability of Rb
- Test It Onsite Before The Event
- Have A Backup Plan Just In Case





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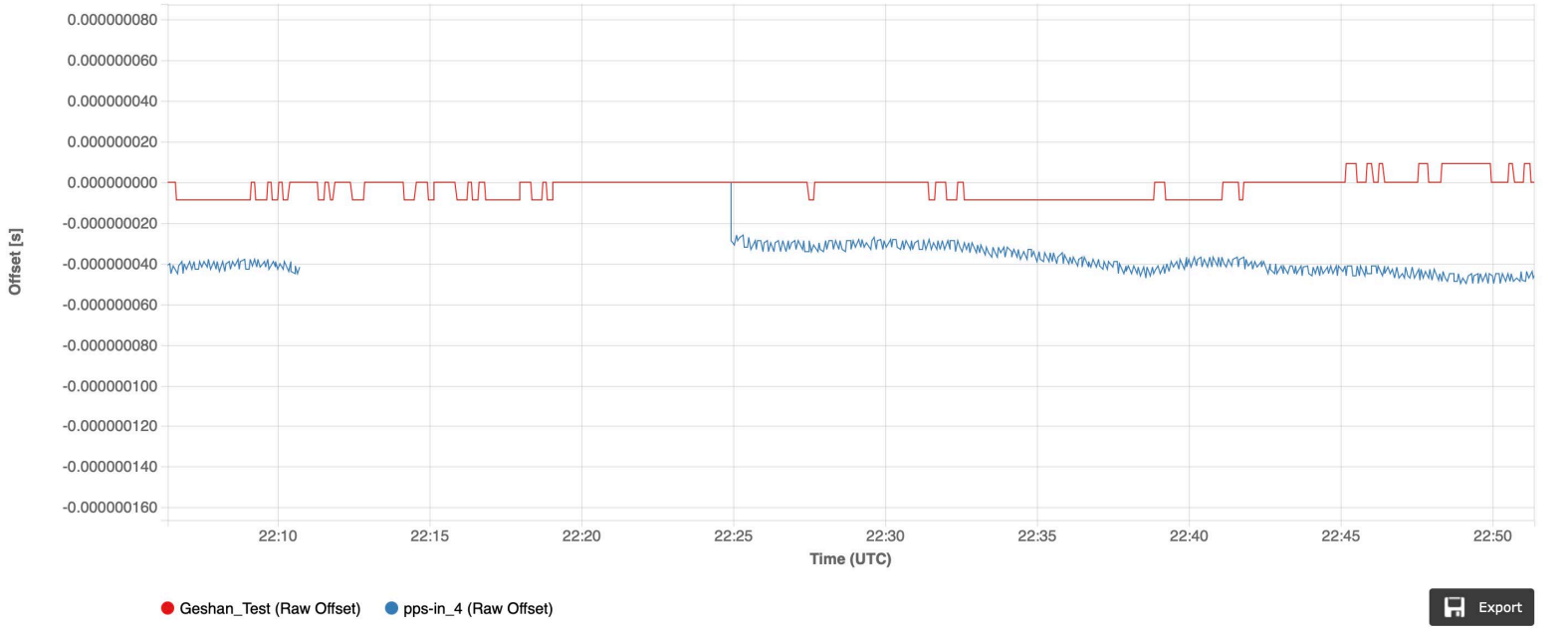


The Frequency Reference

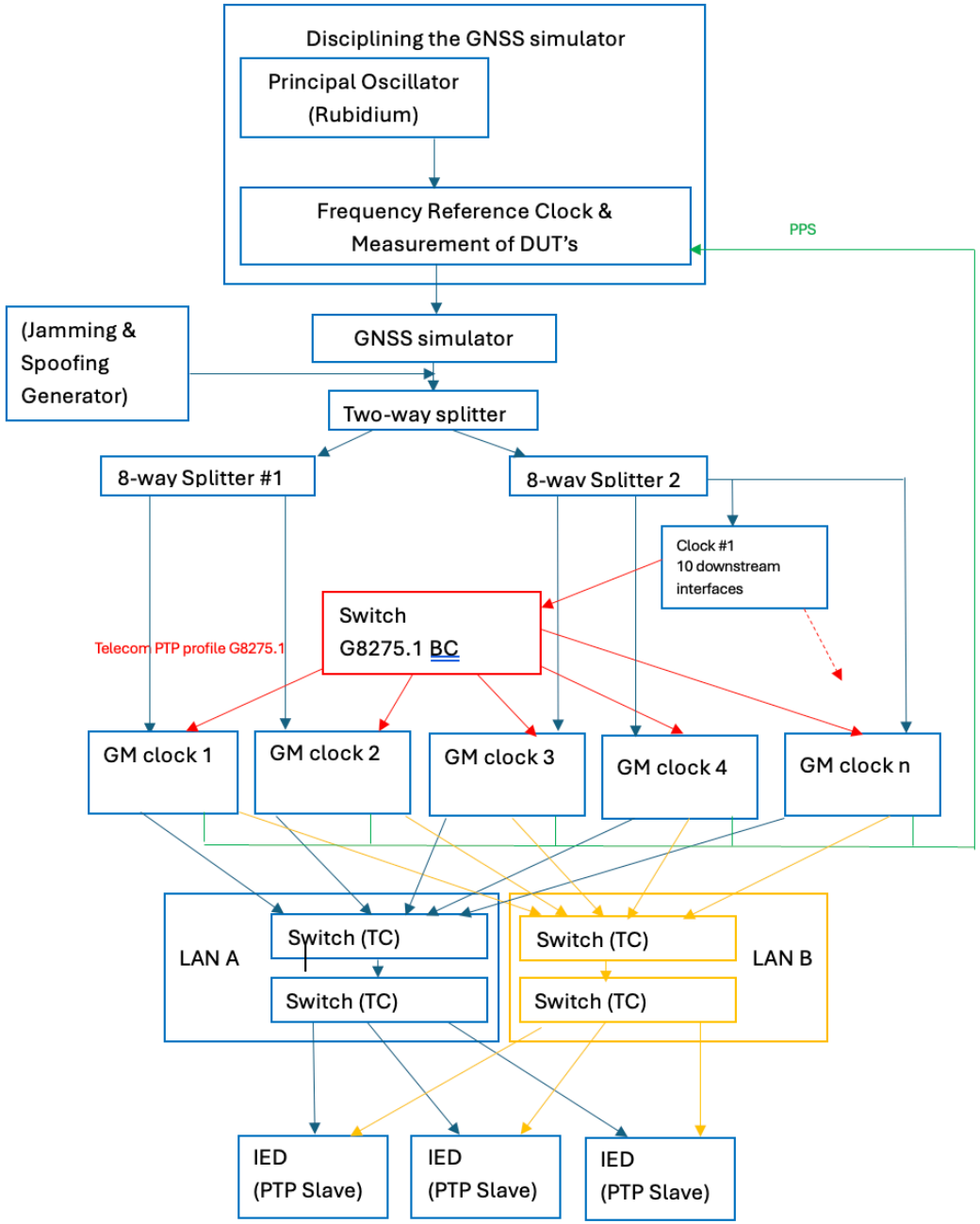
- Test It Prior to Arriving
- Test It Onsite Before The Event
  - Sync It In Hotel Room
  - Tested during setup days wheeling it back and forth from hotel room to convention center after spending approximately 8 hours at convention center and measured approximately a 300ns max drift when synchronized back to GNSS
- Have A Backup Plan Just In Case

The Frequency Reference

- Test It Prior to Arriving
- Test It Onsite Before The Event
- Have A Backup Plan Just In Case
  - Rented An EV To Synchronize Outside If Hotel Room Didn’t Work
  - Planned to park it on the roof of a parking garage and use “dog mode” to maintain climate control inside the vehicle overnight
  - Didn’t end up needing to execute this portion of the plan

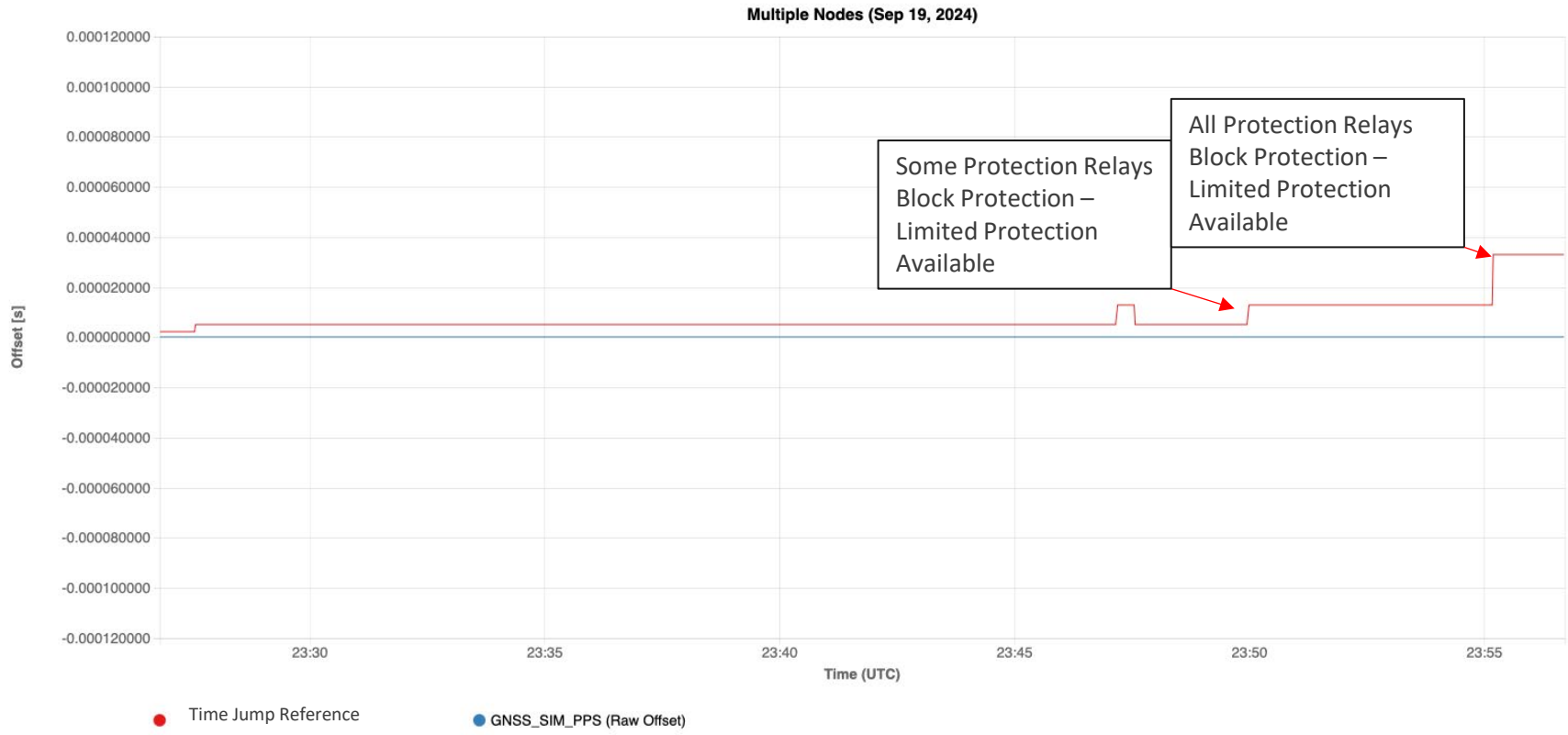
The General Time Sync Test Setup

- Problem: Room At The Venue Was An Interior Room, but we needed stable time in the room
  - Used Mobile Atomic Frequency Reference with GNSS simulator
- Equipment was contributed to the test setup by multiple participating vendors
- Elements of this setup were enabled/disabled and the configuration was modified from this setup for specific test cases.



Tests

- Time Jumps
  - 1µs, 2µs, 3µs, 8µs and 20µs jumps tested
  - At 1µs, all protection relays were able to maintain protection
  - 2-8µs, some relays were able to maintain protection
  - 20µs: All relays lost protection momentarily on functions that require time synchronization



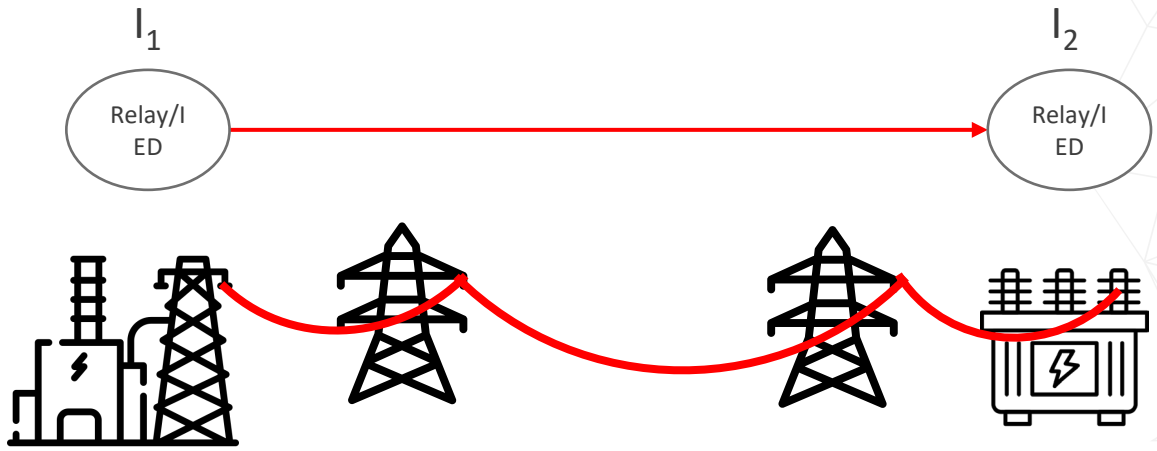
Why Do Time Jumps Matter In A Grid With Digital Substations?

- Distributed Measurements Across Grid
- Correlation Through Timestamped Measurements
- If Timing Fails, A Protection Function May Have A Backup Method. If Not, Protection will be Blocked Temporarily

Example: Line Differential Protection

Normal Operation

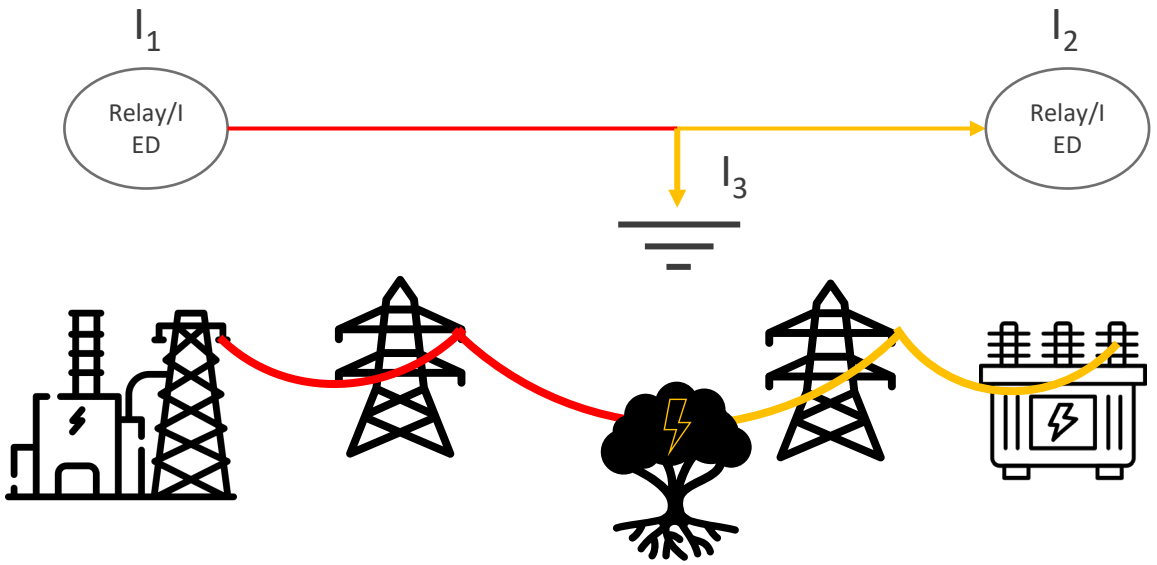
$I_1 = I_2$



Fault Condition

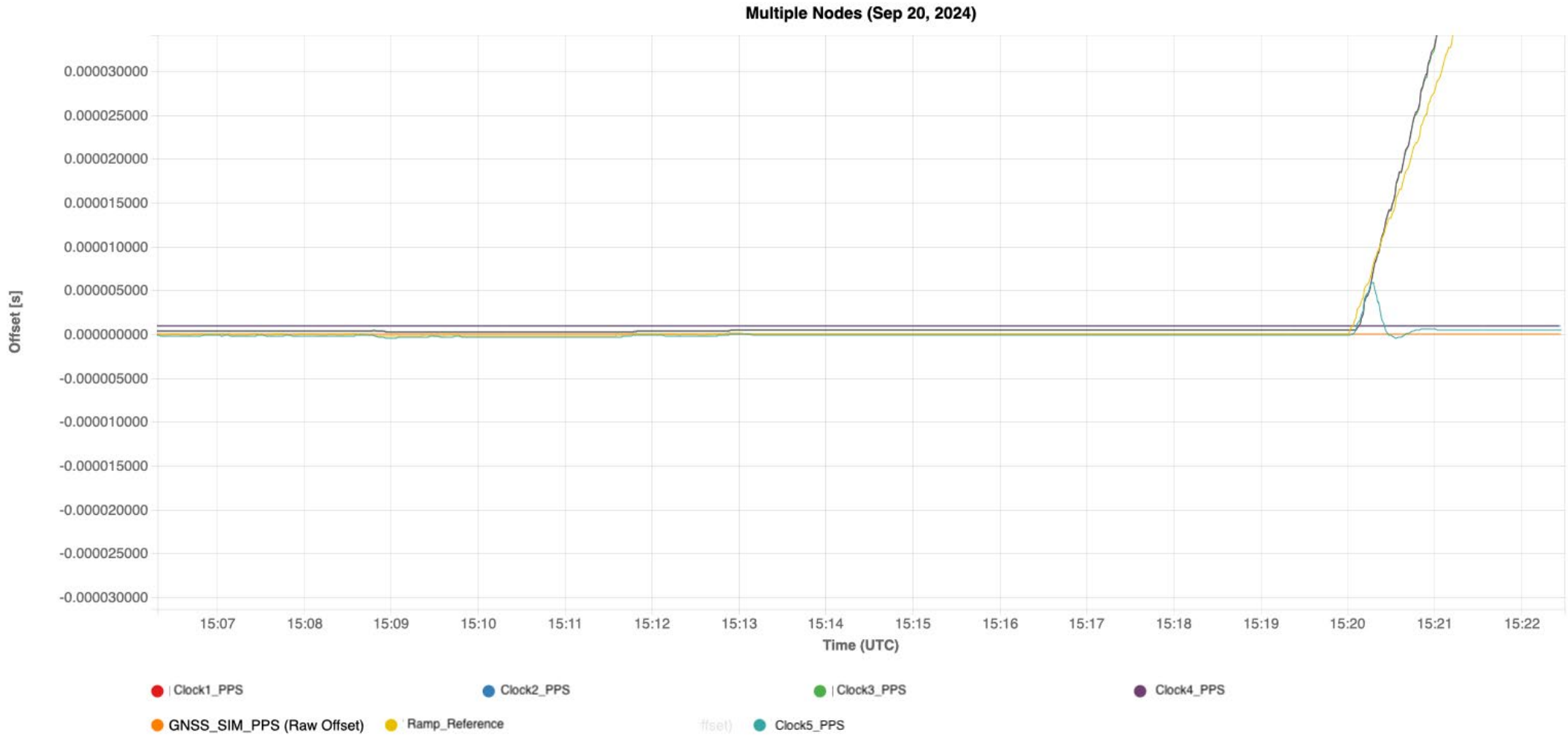
$I_1 = I_2 + I_3$

$I_1 \neq I_2$



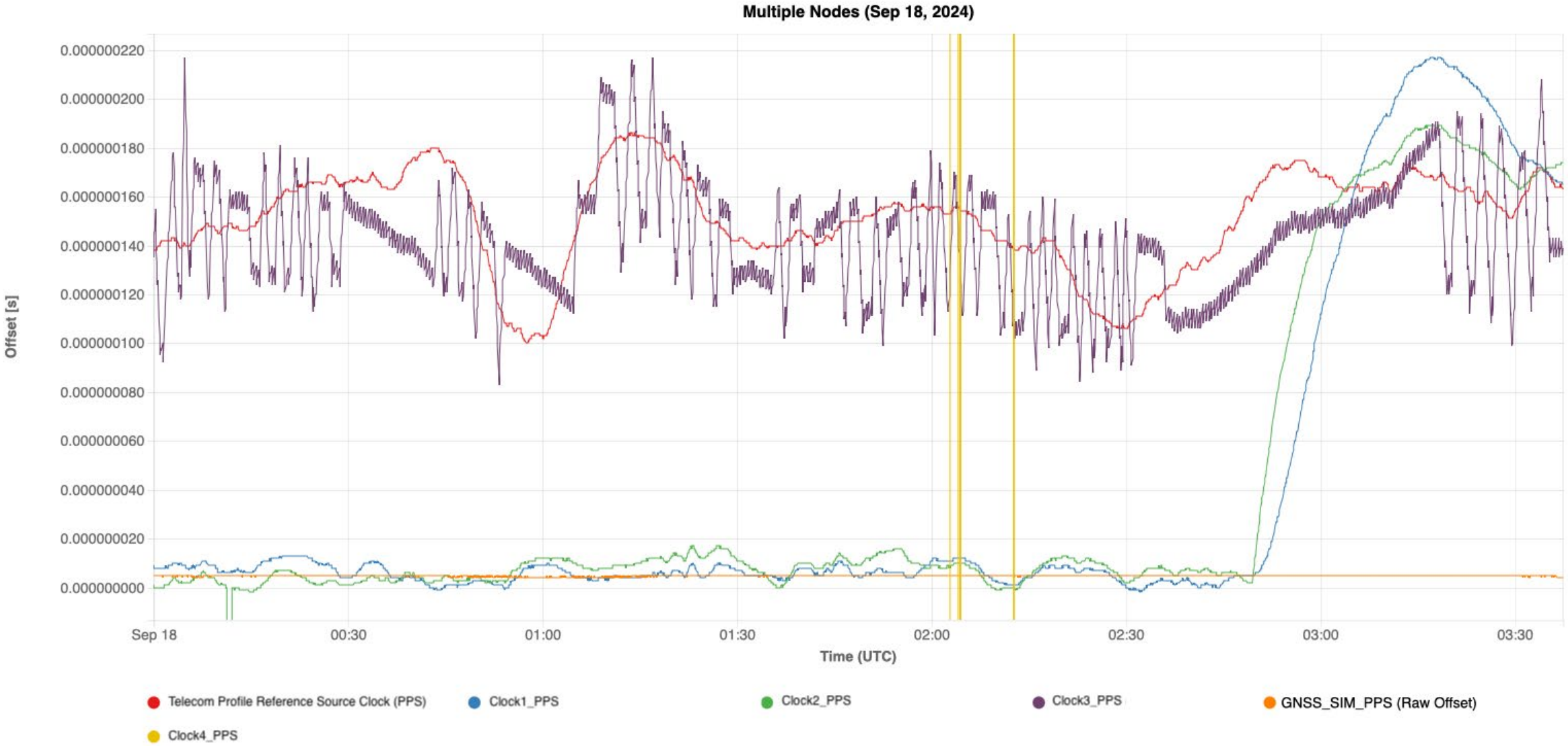
Test: Failover During Ramp Test

- High Ramp Rate (approx. 500ns/s)
- Clock 5 performed as expected
- Clock 4 Did Not Jump As It Was Supposed To And Could Not Follow Ramp Rate
- Clocks 1 and 2 did not synchronize with Ramp Reference Clock



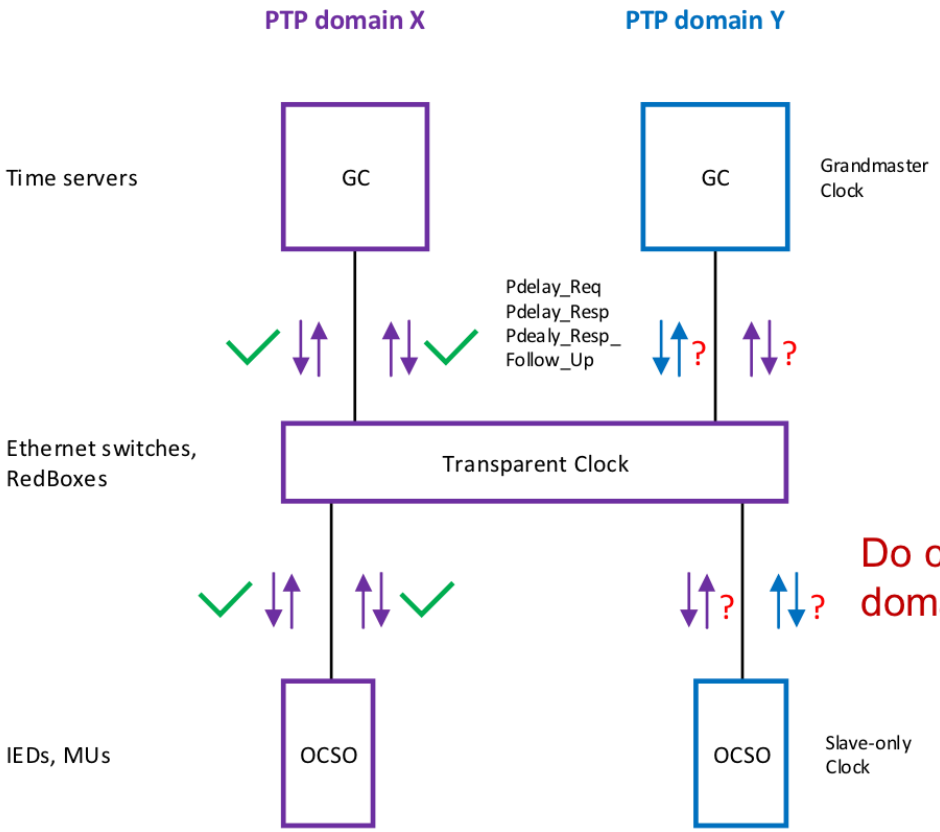
Test: Failover To Alternate Time Source

- Of 4 clocks shown, 2 worked well, 1 was not able to synchronize to either profile, 1 could only synchronize to 1 source
- 2 out of 3 clocks participating in test were able to switch from GNSS to Telecom Profile Reference



Test: Multi-Domain Test for TCs

- Many Vendors Participated and This Exposed An Issue Where Transparent Clocks Was Able to Respond to Messages From Multiple Domains, But Could Only Make Requests In a Primary Domain

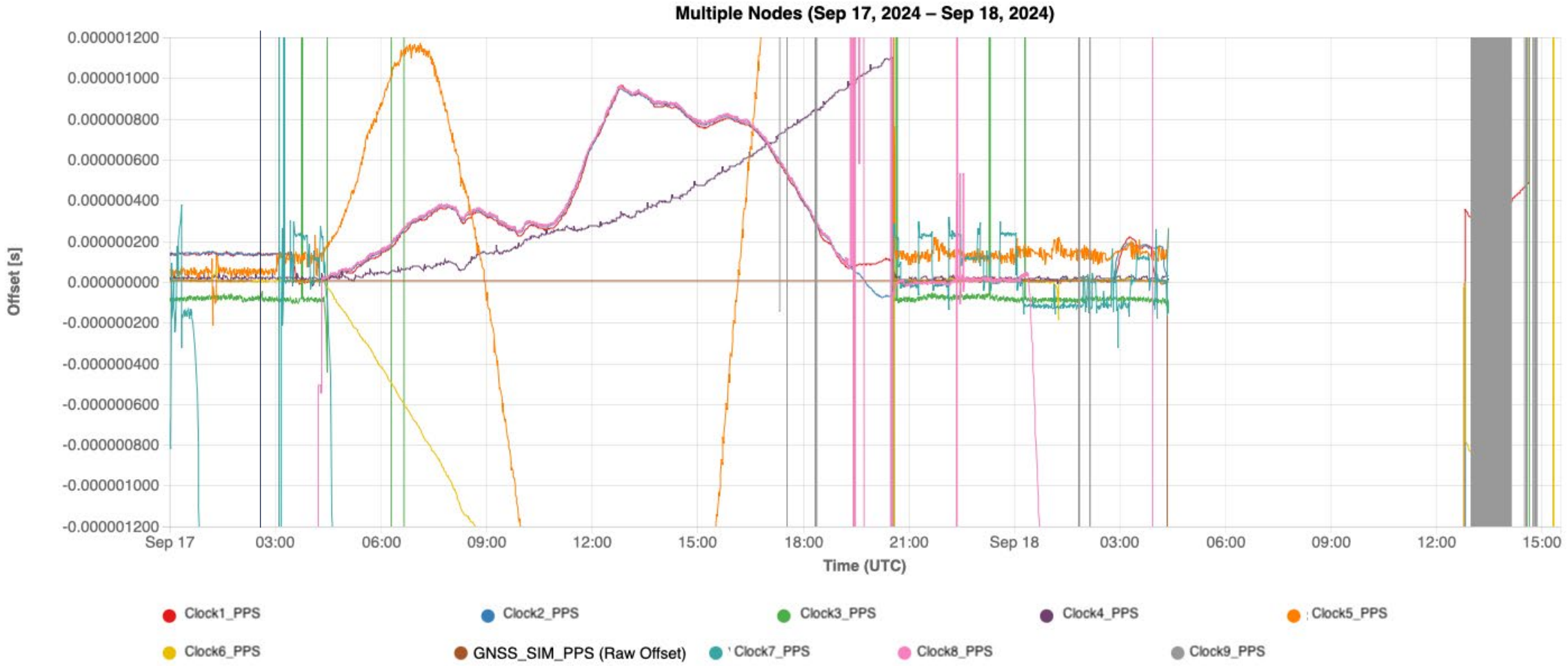


- Clocks send Pdelay_Req msgs with their own domain number.
- Clocks should accept received Pdelay_Req msgs with different domain number.
- Clocks should copy the received domain number to outgoing Pdelay_Resp, Pdelay_Resp_Follow_Up msgs.

Do clocks accept received Pdelay_Req msgs with different domain number and respond correctly to them ?

Tests: Holdover Overnight Test

- Utilized Rb Atomic clock as reference
- Clock 4 has an ideal holdover curve
- Clocks 1 and 2 were synchronized with each other



Tests: Holdover Overnight Test 2

- Utilized Rb Atomic clock as reference
- Clocks 2, 3, and 5 stayed within 2µs
- Clocks had different oscillator classes
  - Some had TCXO and some had OCXO
- Highest offset was approximately 70µs before reconnecting to the GNSS simulator

Takeaways & Conclusions

- Time Jumps greater than 2µs Can Cause Protection Issues
  - Synchronizing Clocks With Each Other Can Mitigate a jump on a failover between two clocks in holdover
- Holdover and Jitter can vary significantly between different clocks with similar oscillator classes
- TC equipment is able to respond multiple domains, but can only make requests in a single domain
- Some clocks cannot synchronize to multiple reference sources
- No Matter How Confident You Are In Your Lab Tests, Test Equipment At An Interop
  - Everyone Found Some Issues To Correct
  - This Helps The Vendors, the Utilities, and the ultimately the grid become more resilient in general

Thank You For Your Time

The Synchronization Experts.