Performance Testing of the Unified Grid Control Platform

Phase 1 Testing progress

Paul Myrda
Sr Program Manager

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Unified Grid Control Platform

1. Why does the electric utility industry need a new unified grid control infrastructure?
2. Review of existing PCM architecture
3. UGCP Substation Architecture
4. UGCP Wide-Area System Integration Architecture
5. Features and Benefits of the new UGCP architecture
6. Integrating Current Electric Utility Technologies in UGCP
7. New UGCP Elements to Integrate
8. UGCP Enterprise Integration - Technical Operations Center (TOC)
9. Cybersecurity
10. UGCP Business Benefits Summary
11. Roadmap for UGCP Advancement
12. Call to Action


EPRI

Unified Grid Control Platform for the Carbon-Free Future

White Paper — Technology Innovation

Why does the electric utility industry need a new unified grid control infrastructure?

Product ID: 3002021252

Overview

Why does the electric utility industry need a new unified grid control infrastructure?

- *Grid is undergoing massive changes and existing techniques may not effectively support future needs.*

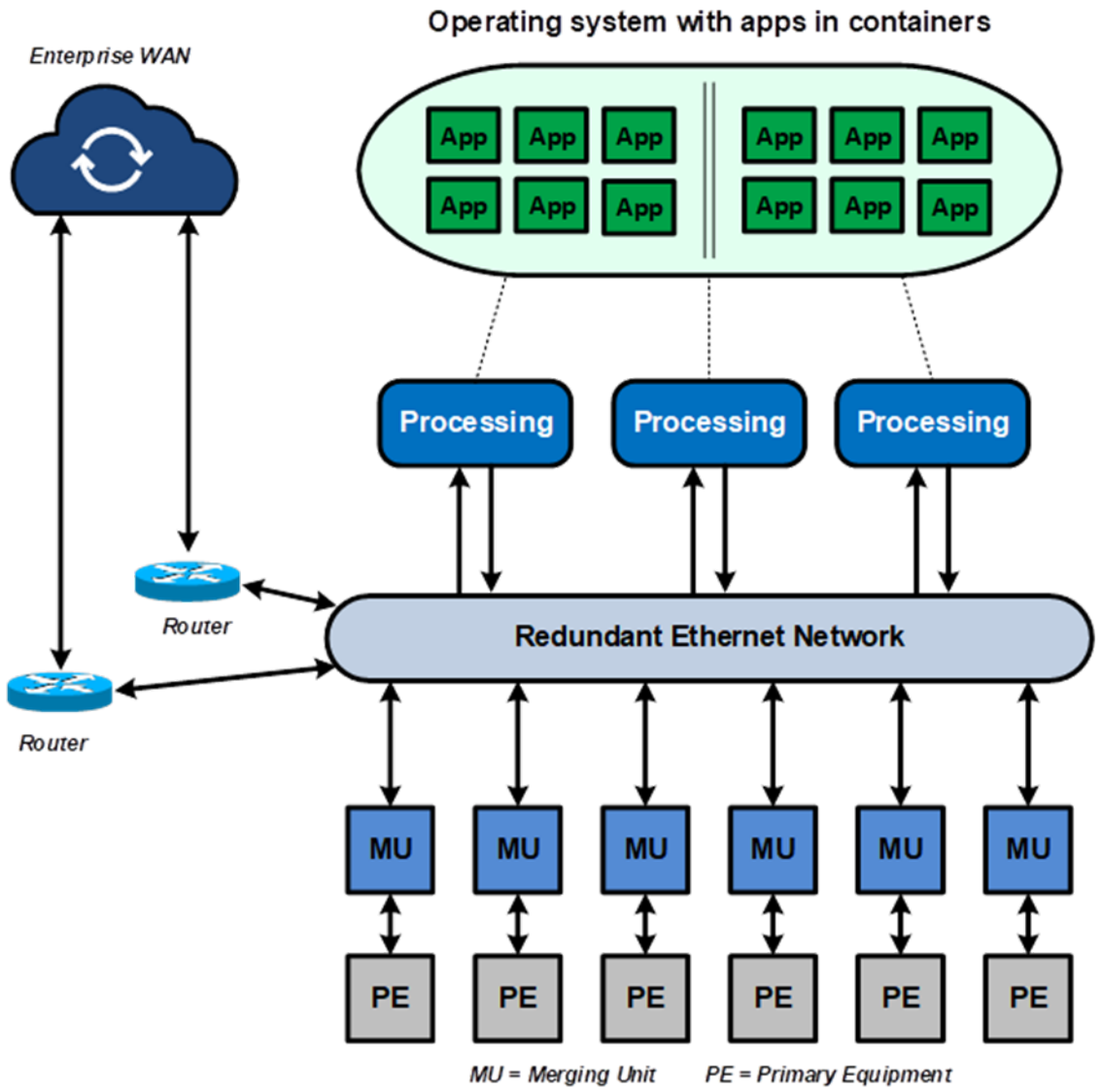
Review of existing PCM architecture

- *Many of the existing protection, control and monitoring approaches are dated and not easily adapted to future needs*

UGCP Substation Architecture

- *Many useful technologies have been developed however adoption has been slow to materialize*

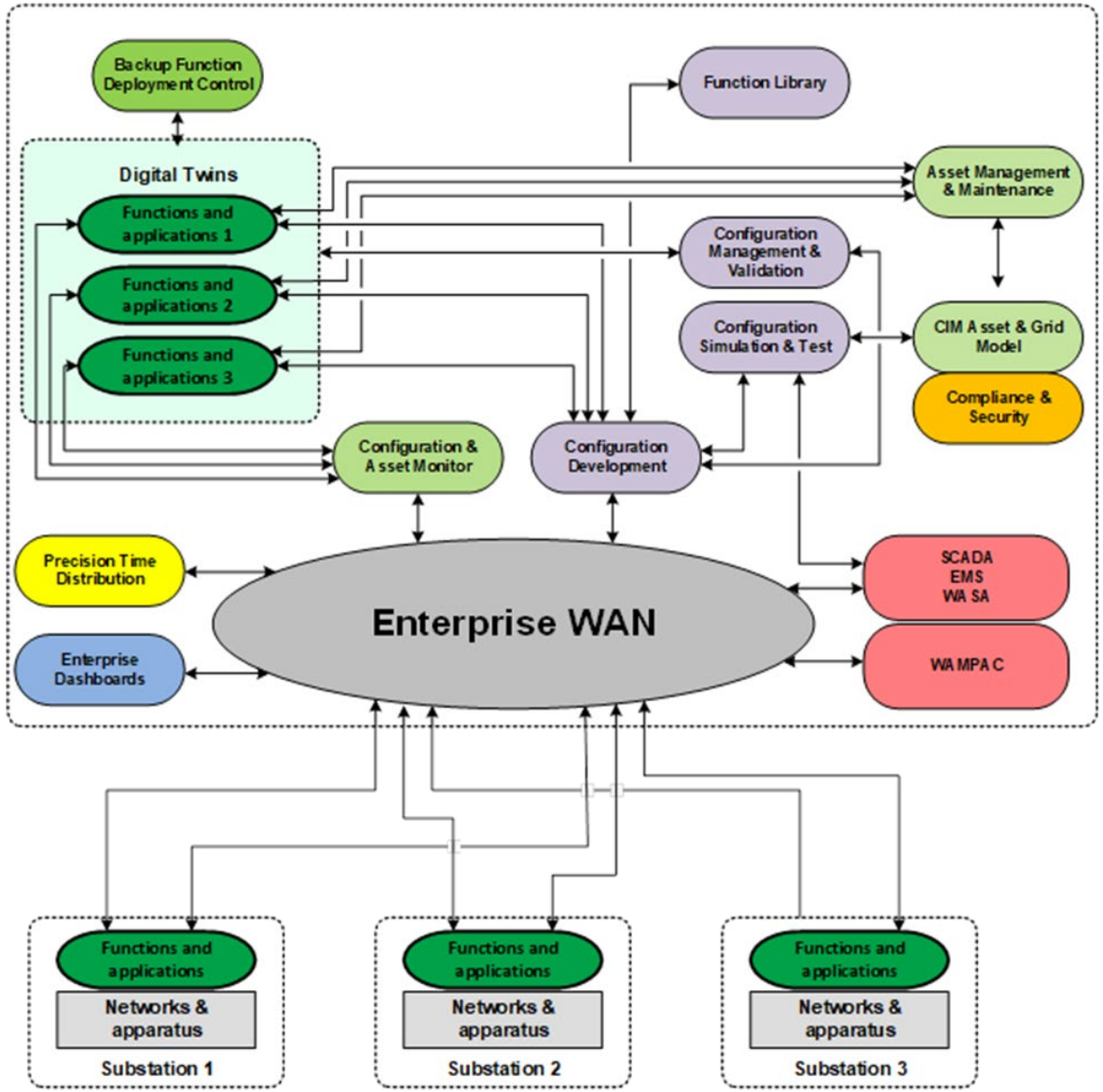
UGCP Substation Architecture



Architecture

- UGCP Wide-Area System Integration Architecture
  - *The distributed processing and networking array yields redundancy, maintainability, sustainability, and flexible deployment of applications with little or no disturbance to operations or to business and management processes.*
- Features and Benefits of the new UGCP architecture
  - *Looks beyond the substation and enables modern IT/OT management techniques employed widely by data centers*
- Integrating Current Electric Utility Technologies in UGCP
  - *Capitalizes on international standards , modern modeling tools, real-time services and more.*

UGCP Overall System Configuration



Leverages New Elements

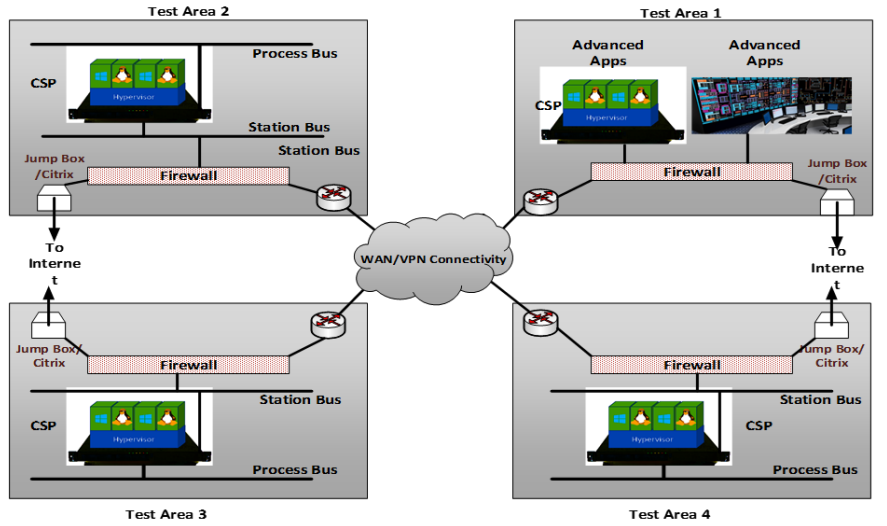
- New UGCP Elements to Integrate
  - *Containerization and isolation, redundancy, distributed and remote network management and security tools, big-data processing platforms, analytic tools and artificial intelligence*
- UGCP Enterprise Integration - Technical Operations Center (TOC)
  - The TOC is not a physical center but an integration of utility operating functions with widespread access to controlled enterprise-wide sharing of real-time grid information and analysis results for grid management
- Cybersecurity
  - *Cybersecurity, along with physical and operational security, will always be a central focus for UGCP as it employs distributed computing systems and communications*

Next Steps

- Unified Grid Control Platform (UGCP) - Laboratory Demonstration Project – Phase I
  - UGCP demonstrations are proposed in three phases. This project is only addressing Phase I. Subsequent phases will be completed as separate projects, if each prior phase has a successful outcome. The overall objective is the development of performance metrics and test setups that can be utilized to test different hardware and software combinations.

Phase I: Develop baseline/foundational test set-ups and metrics for the following:

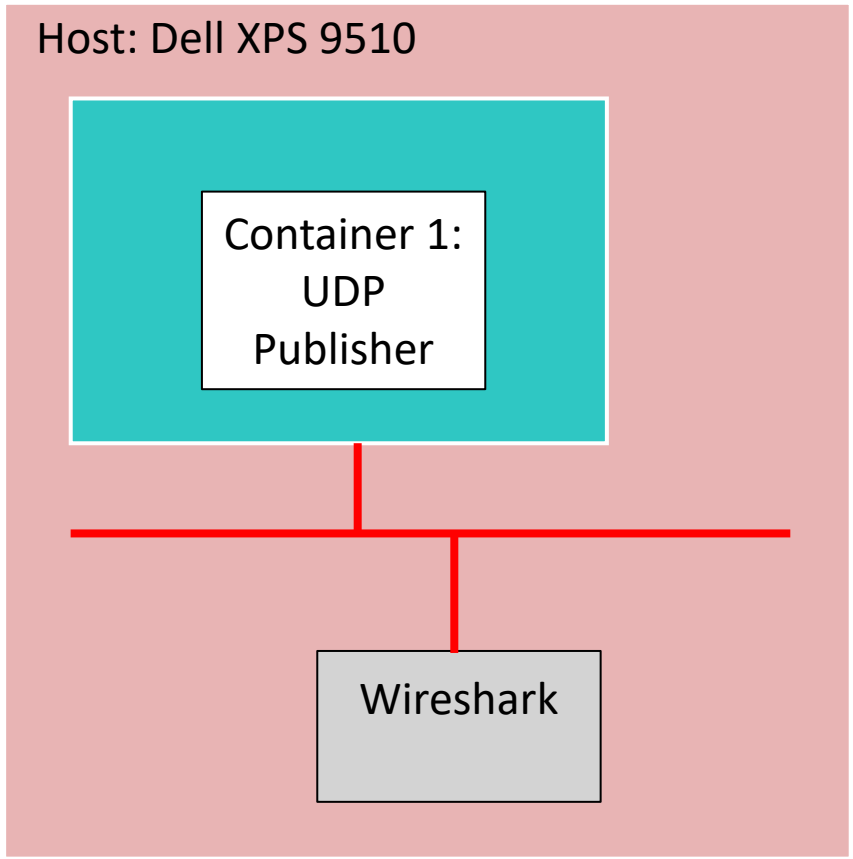
- Different architectures of container redundancy solutions and the impact of container and I/O loading on recovery from failure.
- PTP/IEC 61850-9-3 inaccuracies introduced via various
- Time synchronization solutions within a hypervisor environment.
- Impact of hypervisor and container loading on Sample
- Values subscription and utilization.
- Impact of hypervisor and container loading on GOOSE subscription, performance, and retransmission.
- Review of the performance and supervision capability of the hardware platform/hypervisor combination being utilized in this demo phase.



Price of Project: Phase I is $95,000

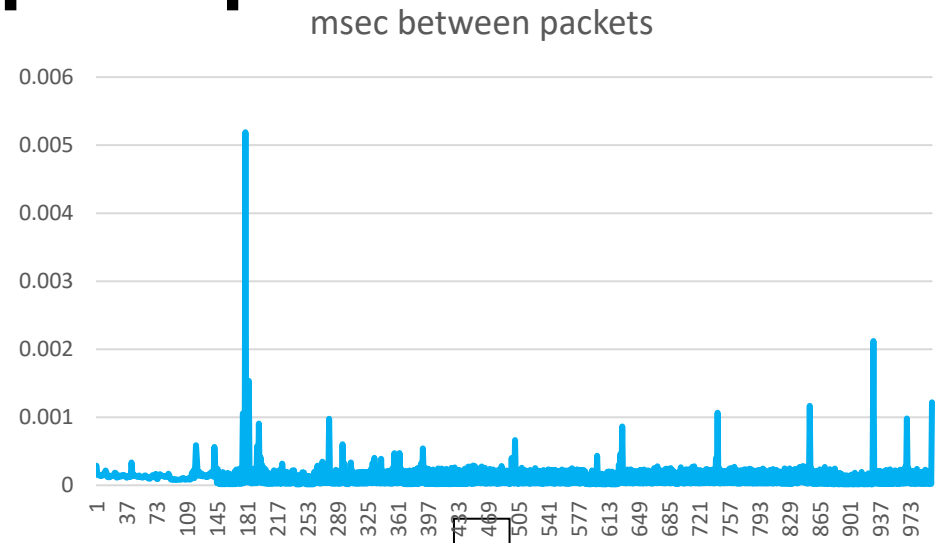
(A minimum of four utilities are needed to start project)

Proving Methodology Test 1: 100 µsec publication



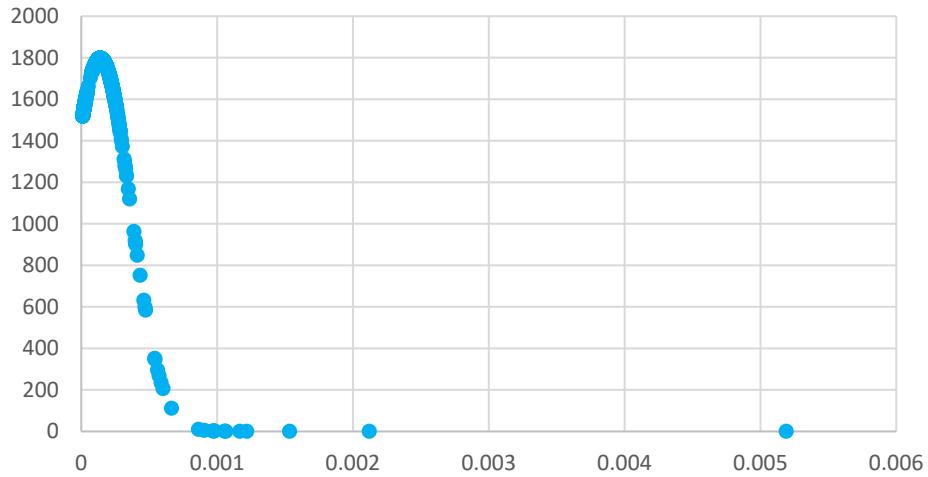
1000 packets analyzed

Analysis



Excel

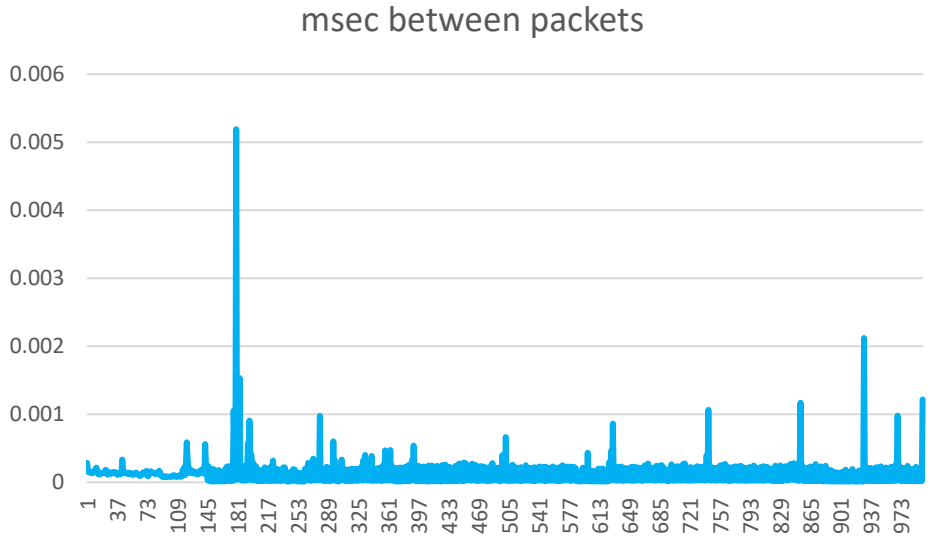
Units are seconds:
(e.g. .001 is 1 msec)

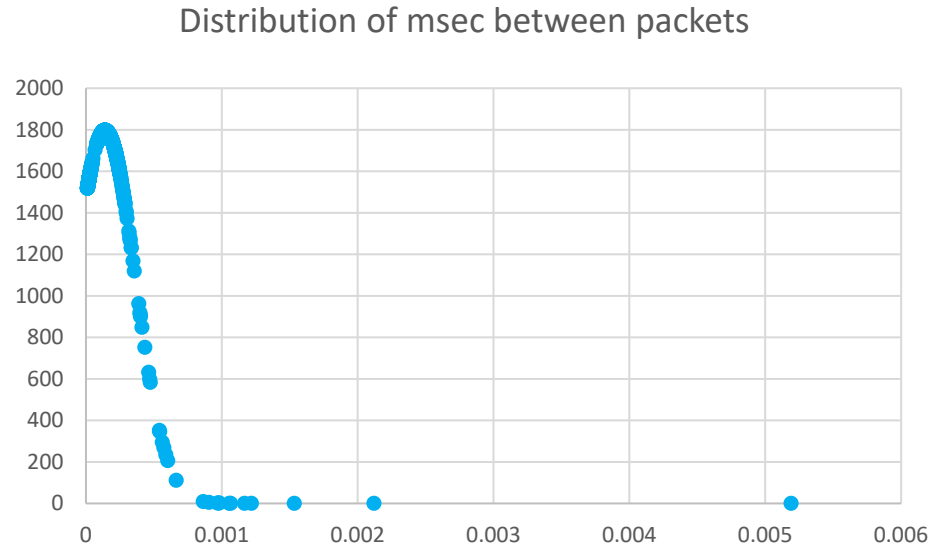


Average:	0.000141
Standard Deviation:	0.000222
Minimum:	0.000012
Maximum:	0.005191

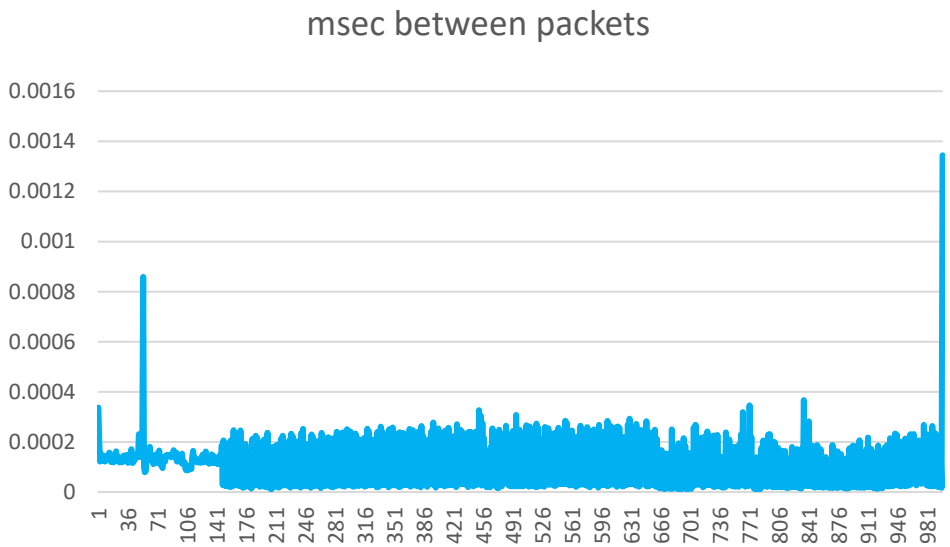
Impact of host/hypervisor

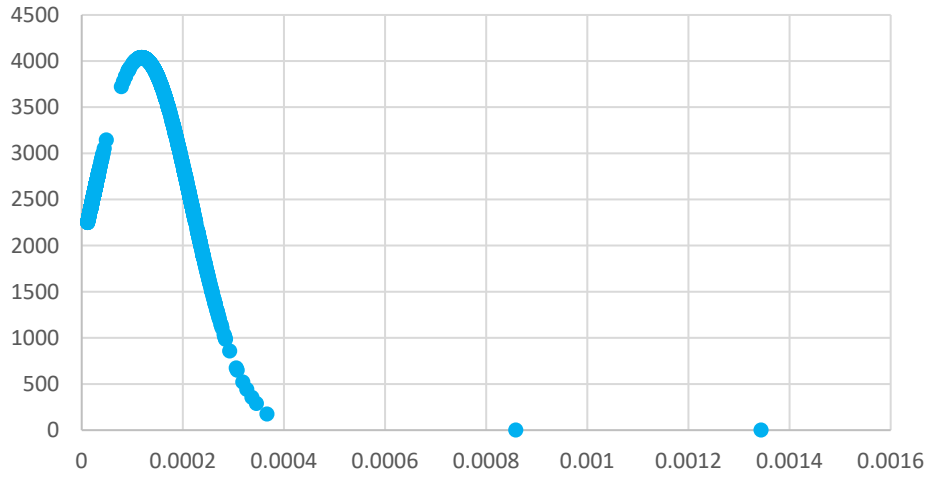
Average:	0.000141
Standard Deviation:	0.000222
Minimum:	0.000012
Maximum:	0.005191





Average:	0.000127
Standard Deviation:	0.000119
Minimum:	0.00001
Maximum:	0.000629





Some unexpected results:

- The higher the loading (without exceeding host), the tighter the standard deviation is.
  - Length of run was approximately 1 sec
  - Need better tools to record and analyze more information (e.g. 10 minutes or more).
- Need to evaluate where distribution becomes an issue?
  - This is a user issue, but would suggest as shifts become more beyond 0.0005, reason for concern.
- Need to test IEDs in a similar fashion to determine their base variance.

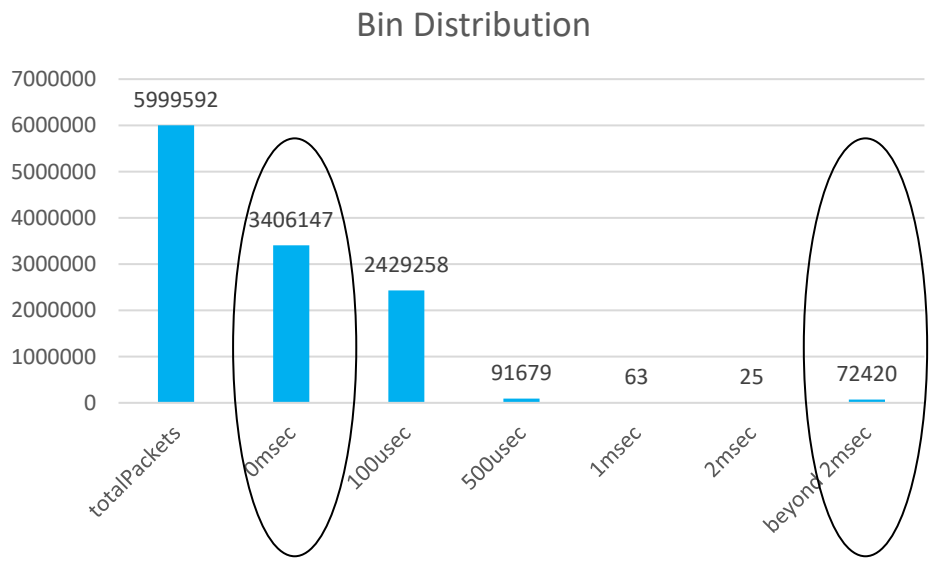
Deeper Dive

Need Better Time Stamping

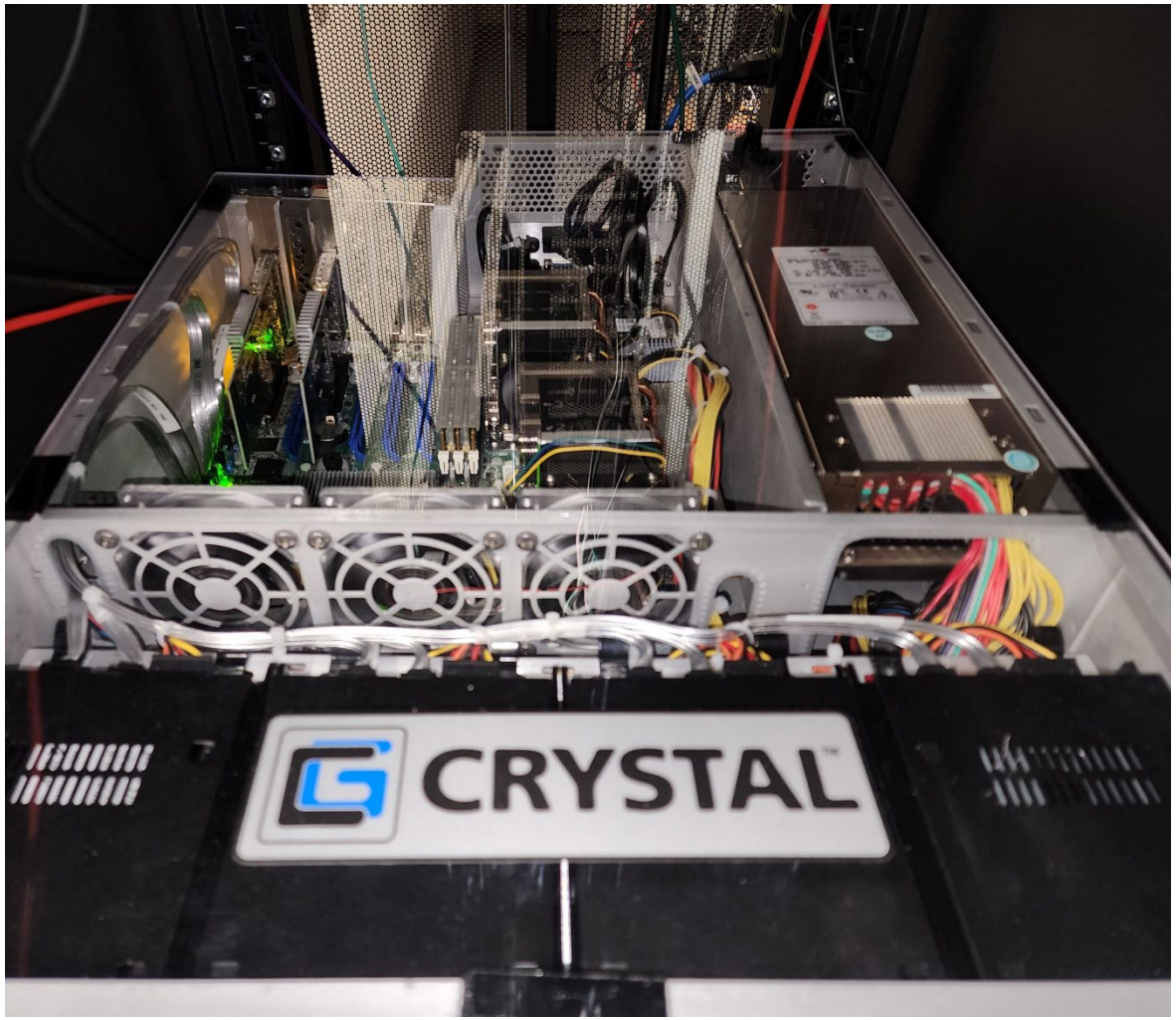
1265…	106.780116	192.168.33.44	224.0.0.1	UDP	63 49763 → 11000 Len=21
1265…	106.780117	192.168.33.44	224.0.0.1	UDP	63 49763 → 11000 Len=21
1265…	106.780117	192.168.33.44	224.0.0.1	UDP	63 49763 → 11000 Len=21
1265…	106.780117	192.168.33.44	224.0.0.1	UDP	63 49763 → 11000 Len=21
1265…	106.780117	192.168.33.44	224.0.0.1	UDP	63 49763 → 11000 Len=21
1265…	106.780118	192.168.33.44	224.0.0.1	UDP	63 49763 → 11000 Len=21

May force a refocus on what caused this condition.

Could be caused by buffering, time accuracy, VMWare slicing of Ethernet Interface, other.



Test platform and status



Test server specifications

- Dual Xeon Gold 6238T processors
  - 22 cores per processor @ 1.9GHz
    (44 threads, 3.7GHz max Turbo)
- 48GB ECC RAM
- 500 GB Storage (320GB usable)
- VMware ESXi 7.0U3
- Up to ten GbE connections
  - Two quad port SFP server NICs
  - Two onboard NICs (one 10GbE, one GbE)

Server being supplied and supported by Crystal Group

Network specifications

- ABB AFR677, ABB AFS675, & ABB AFS670
  - SW Version 9.1.03
  - LC MM fiber, GbE SFPs, and copper GbE

Supported by Hitachi Energy

Status:

Ready to import test VMs. Network configuration nearing completion.

Obstacles to testing

- Supply chain
  - ABB Networking equipment requires Hirschman (Belden) SFPs: 20+ week lead time across the market
  - Cisco/Nokia/Generic fiber SFPs failed to be compatible with ABB hardware

  Solution 1: Identified copper GbE SFPs for server that allow for immediate testing using built-in copper GbE connections in ABB hardware.

  Solution 2: Axiom was able to create a couple of Hirschman compatible 1000BASE-SX LC MM (850nm) SFPs. Initial testing of Axiom SFPs resulted in link and data validation. RFC2544 performance testing revealed nearly identical performance to comparable Intel SFPs. The delay was nearly identical, but the variance was slightly higher at .05 microseconds. SFPs have been ordered and we are waiting on delivery of goods.

  Axiom effort supported by Shields Electronics Supply

  - HSR/PRP card still needed
    - Advantech ECU-P1524SPE recommended by Crystal Group

- Network Configuration
  - Network hardware needed SW updates

  Solution: Hitachi Energy support provided latest SW for hardware. All hardware has been updated successfully.

  - Configuration guidance/validation

  Solution: Hitachi Energy support provided a model configuration Monday 9/12 that is being modified to meet project testing needs. Supplied configuration was modified to meet the UGCP testing needs. Modified configuration was reviewed by Hitachi Energy and no obvious concerns were identified.

  - VMware virtual NIC transmission buffering disable needs to be identified

  Solution: A ESXi shell command has been identified for the Vmkernel adapters that appears to allow us to toggle the buffering of traffic for the virtual NICs. Will need to evaluate impact this change has upon system performance.

Select Grid Edge Activities Impacting Industry

Key challenge

Optimize system operation and increase reliability and flexibility of the grid

- Red Eléctrica and Elewit are working on the EPICS (Edge Protection and Intelligent Control Solution) project, which aims to create a flexible, scalable, replicable, manageable, programmable, cyber-secure and adaptable hardware and software platform that can be used in many different application environments.
- IEEE PSRC HTF 45 - Guide for Centralized Protection and Control (CPC) Systems within a Substation
- IEEE PSCCC P21 - System Architectures Supporting the Virtualization of Substation Protection and Control Applications
- ARPAe 2018 - Resilient, Cyber Secure Centralized Substation Protection (RCSP)
- EPRI – Unified Grid Control Platform – Testing the use of Virtualization in Substations
  - So Co, AEP, SRP, NG-UK, SCE
- AG 22, Advisory Group on strategic developments and technological, operational and organizational matters for TC57
  - TASK FORCE 3: Provide an end-to-end TC57 vision on future applications for power systems.
- ABB - Smart substation control and protection SSC600
- Intel - Performance and scalability of virtualized system for centralized protection at the substation
  - With support from Kalkitech India.

Questions

Relevant Publications

- Recent Publications
  - December 2015 – IEEE Power Systems Relaying Committee (PSRC) Report on "Centralized Substation Protection and Control"
  - March 2018 – EPRI Reports on "Setting-less Protection: Centralized Substation Protection and Field Demo" 3002014034 and 3002014035
  - July 2019 – GE Article for CIGRE on "The Substation of the Future"
- IEEE
  - March 2018 – IEES PSRC Launches Working Group H45 to develop "Guide for Centralized Protection and Control (CPC) Systems within a Substation"; target draft completion of December 2021
- CIGRE
  - WG N B5.60 - Protection, Automation and Control Architectures with Functionality Independent of Hardware

EPRI Technology Innovation

Initial research on Setting-less Protection began in 2012 under Grid Transformation TI Project

Setting-less Protection Methods for Grid Transformation

Final Project Report: 3002001846

Program on Technology Innovation: Setting-Less Protection Methods

Final Project Report: 3002004095

Setting-less Protection: Centralized Substation Protection

Final Project Report: 3002014035

Setting-less Protection: Field Demonstration

Final Project Report: 3002014034