Smart Grid Substation Lab

Real Solutions to Real Issues at Utilities

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ELECTRIC POWER RESEARCH INSTITUTE

EPRI Smart Grid Substation Lab

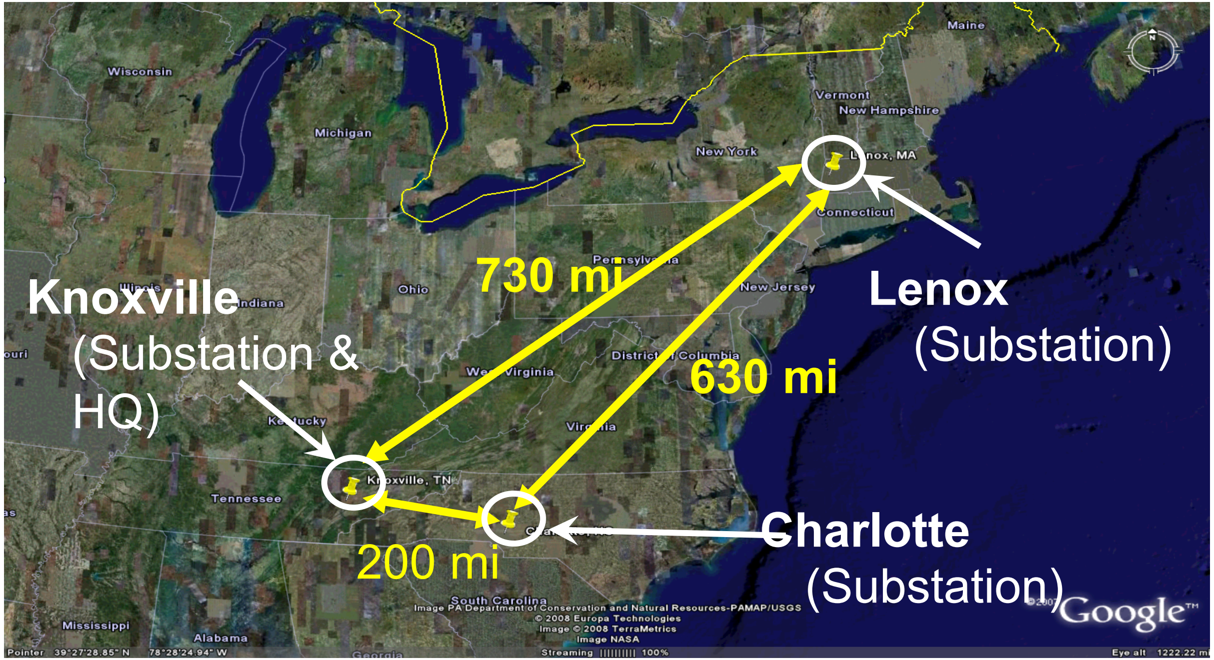
Bringing key industry resources together to explore real-world application of standards

- Environment to test drive approaches and solutions
- Tailor work to focus on high impact areas
  - industry need is great
  - standards are nearly ready for prime time
  - need to explore interoperability or refine understanding with a proof-of-concept
- Vision reflects utility reality & best practices

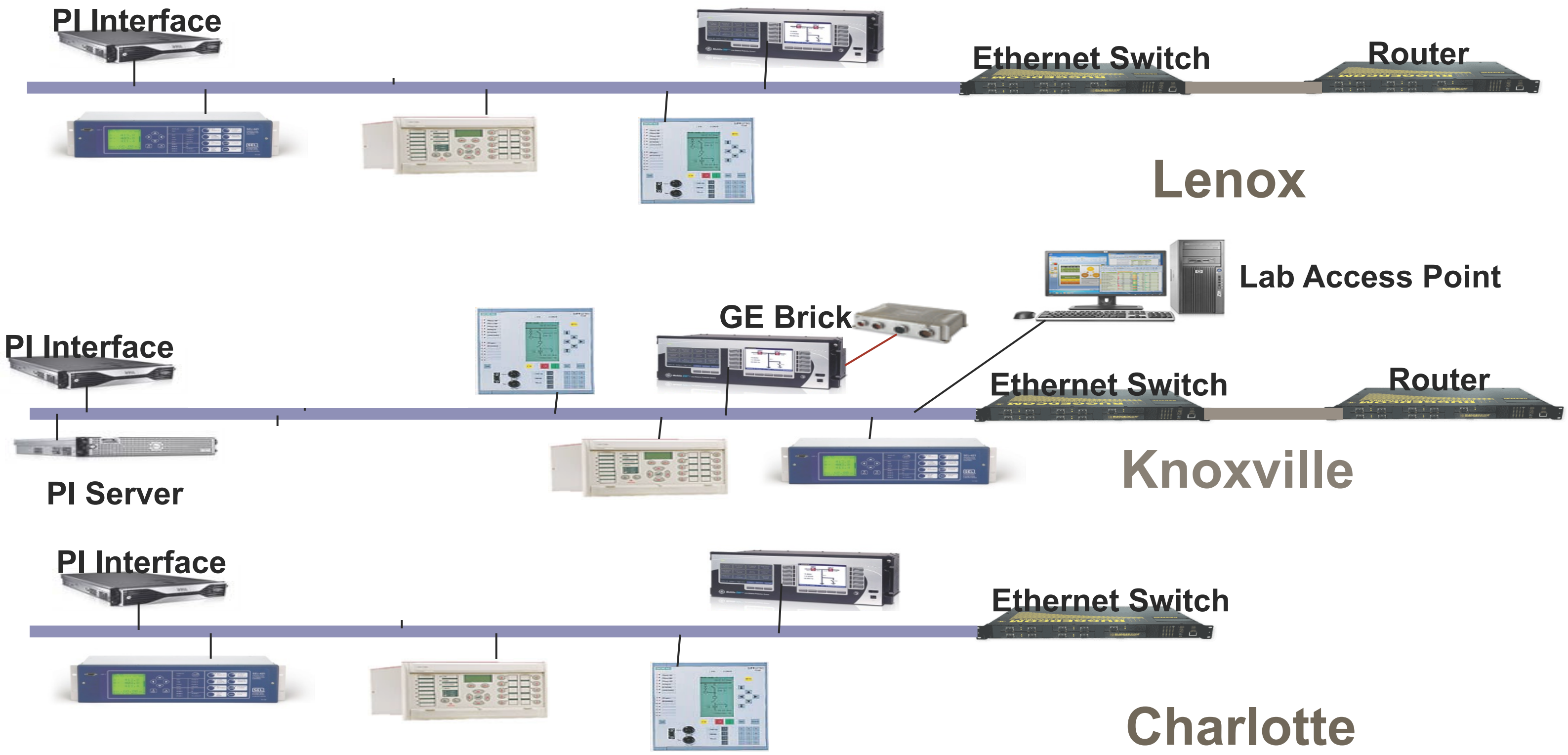
EPRI Smart Grid Substation Lab

- Currently supporting:
  - Synchrophasor demos (C37.118 and 61850-90-5), exploring PMU data sharing without phasor data concentrators
  - LEMNOS, implementing multi-vendor router security interoperability
  - Multi-vendor 61850, demonstrating integration of data from multiple vendor relays
  - Transformer Performance, focusing on standards integration & visualization for the Control Center

SGS Lab Spans 3 Geographic Locations



Architecture of the Lab



Equipment View

Charlotte

Lenox

Knoxville

Historians (Knoxville)

EPRI Transformer Performance Project

- Demonstration project to bring transformer performance information to the Control Center
- Initial phase will be completed in 2011 – expanding activity in 2012 to include additional information
- Combination of EPRI general funding and sponsorship by AEP, Southern, FirstEnergy & CenterPoint
- Driven by:
  - desire to get meaningful asset performance information into the hands of Operations & other utility staff
  - desire to demonstrate how industry standards (61850 and CIM) play key role in deployment and maintainability

EPRI Transformer Performance Project

- Data from a variety of sources
  - classic EMS power system telemetry (MW, MVar, Amps)
  - newer temperature and dissolved gas telemetry
  - routine DGA sample test results
  - leading edge field transformer health monitoring device
- Visualization environment that supports geo-based displays, a rich graphing environment and deployment on tablet devices…

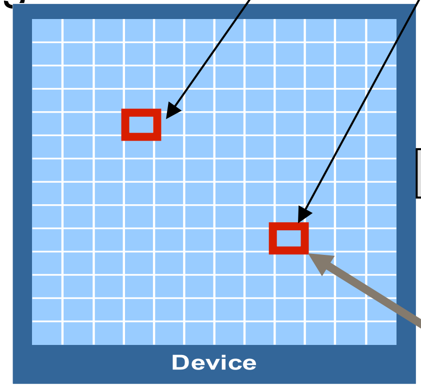
EPRI Transformer Performance Project

- Real value is in the infrastructure
  - 61850 substation device information
  - translated into CIM SCADA messages
  - consumed by historian
  - presented in visualization tool via CIM model based access to historic real-time data

Key Benefit of IEC 61850 Data Model

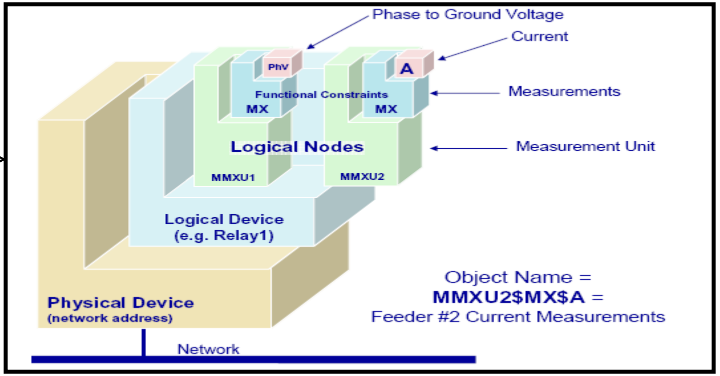
Typical Legacy Protocol Data Model – DNP3

I need to find the MW loading on Transformer 123 -
Is it in register 1154 or 5411?



Apply

IEC 61850 Protocol Data Model

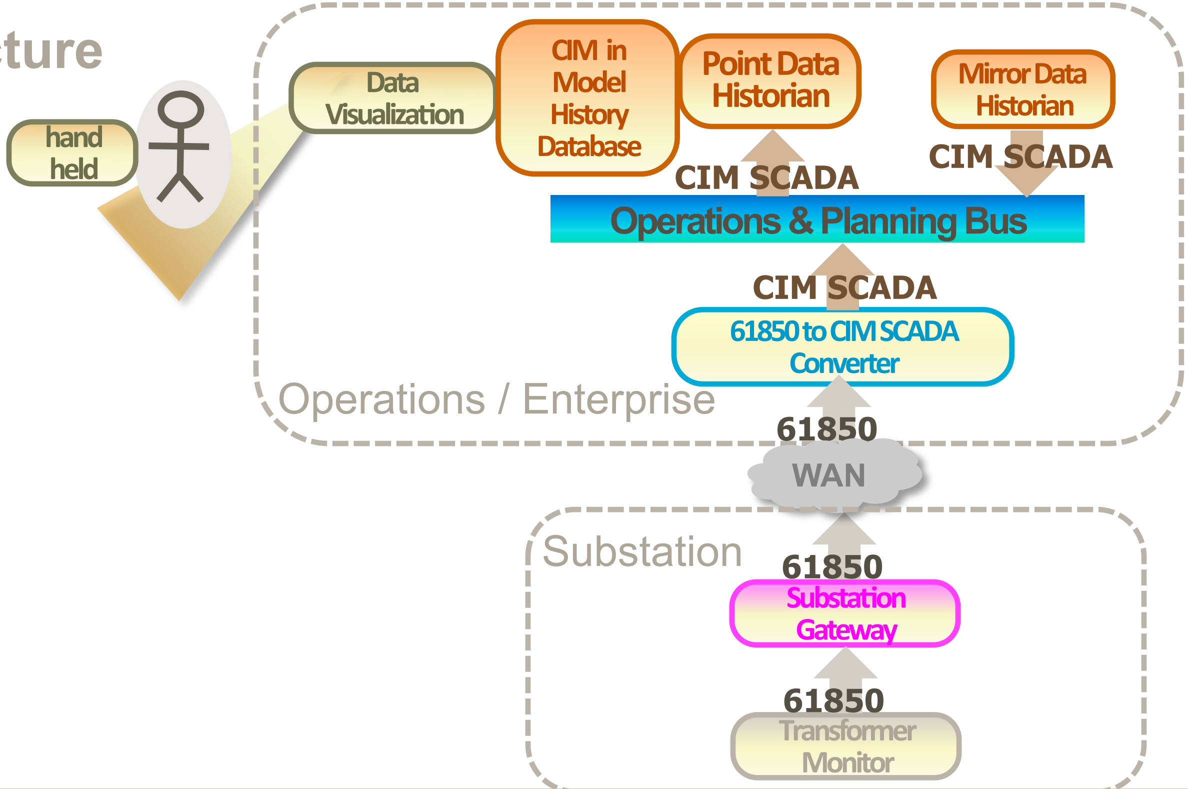


I need to find the MW loading on Transformer 123 -MMXU1MXPhV$PhsA$cValmagf

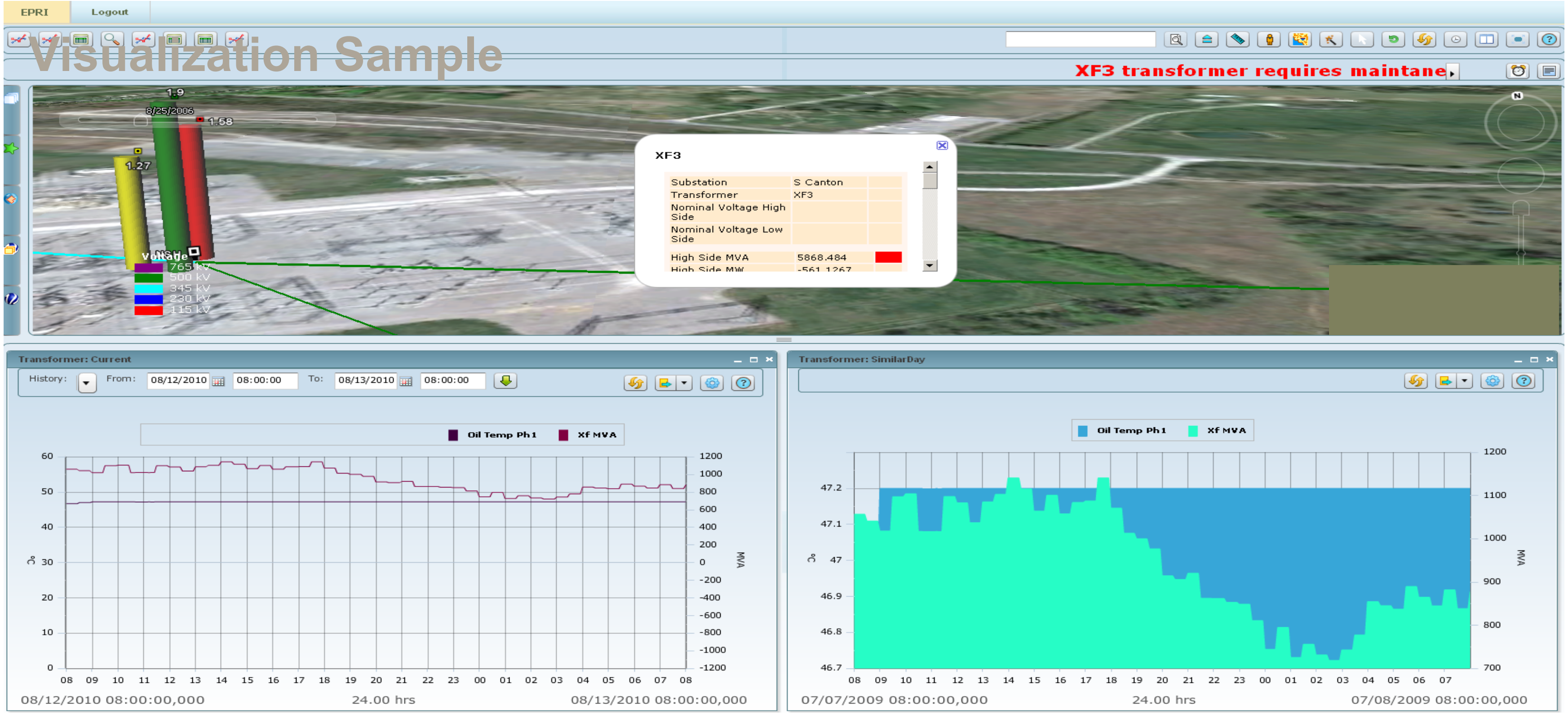
IEC61850 makes the Power System context visible and reduces long-term operating cost

EPRI Transformer Health Project

System Architecture



EPRI Transformer Health Project



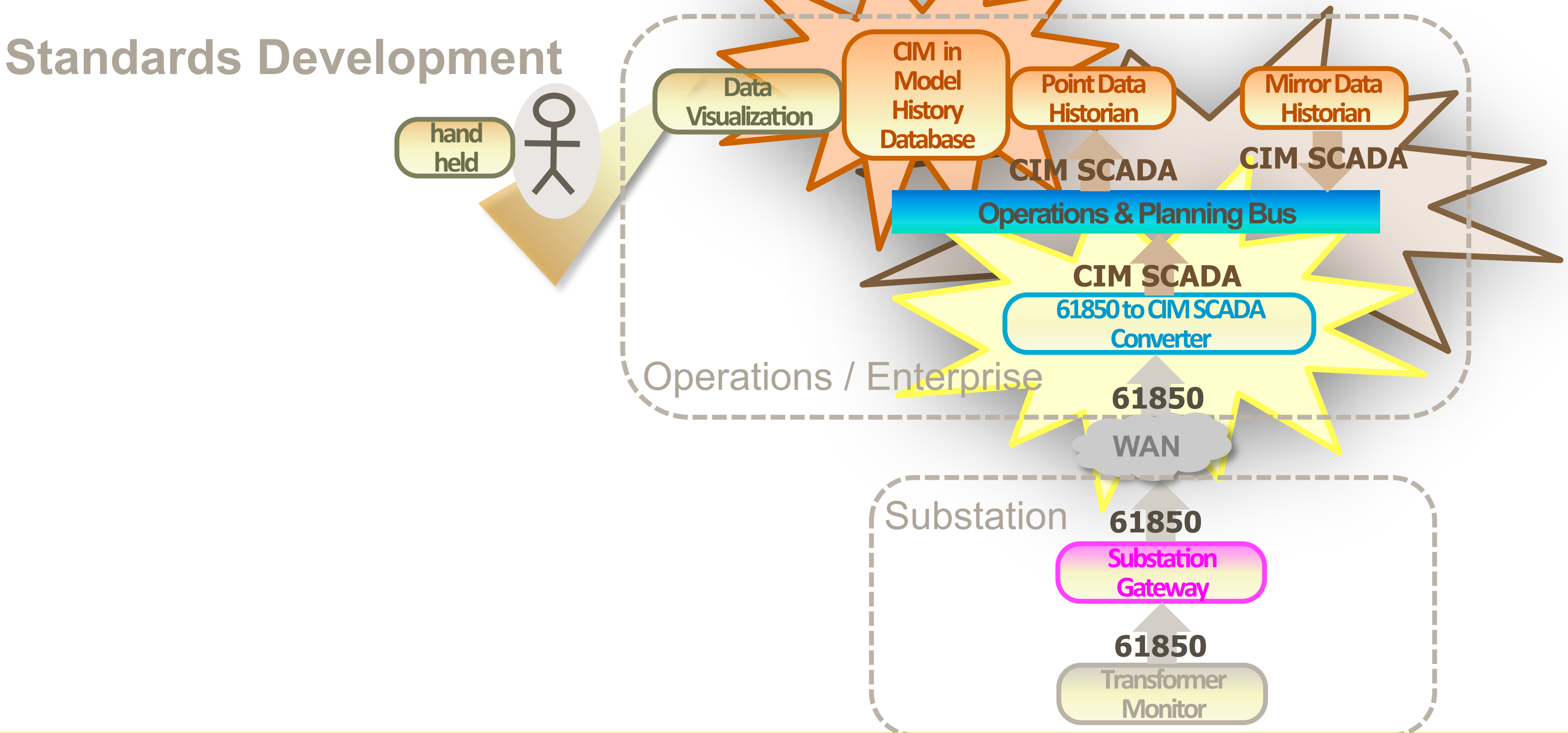
EPRI Transformer Health Project

EPRI Transformer Performance Project

CIM Model in Model History Database is Key

- Model contains
  - Equipment (Transformers)
  - Network topology
  - Substations
  - Links to historic real-time data
  - DGA sample test data
- Allows model-driven visualization tool access to historic real-time data
- Visualization tool retrieval based on industry-standard model -> reusability

EPRI Transformer Transformer Project



Synchrophasor Research

Model Extensions

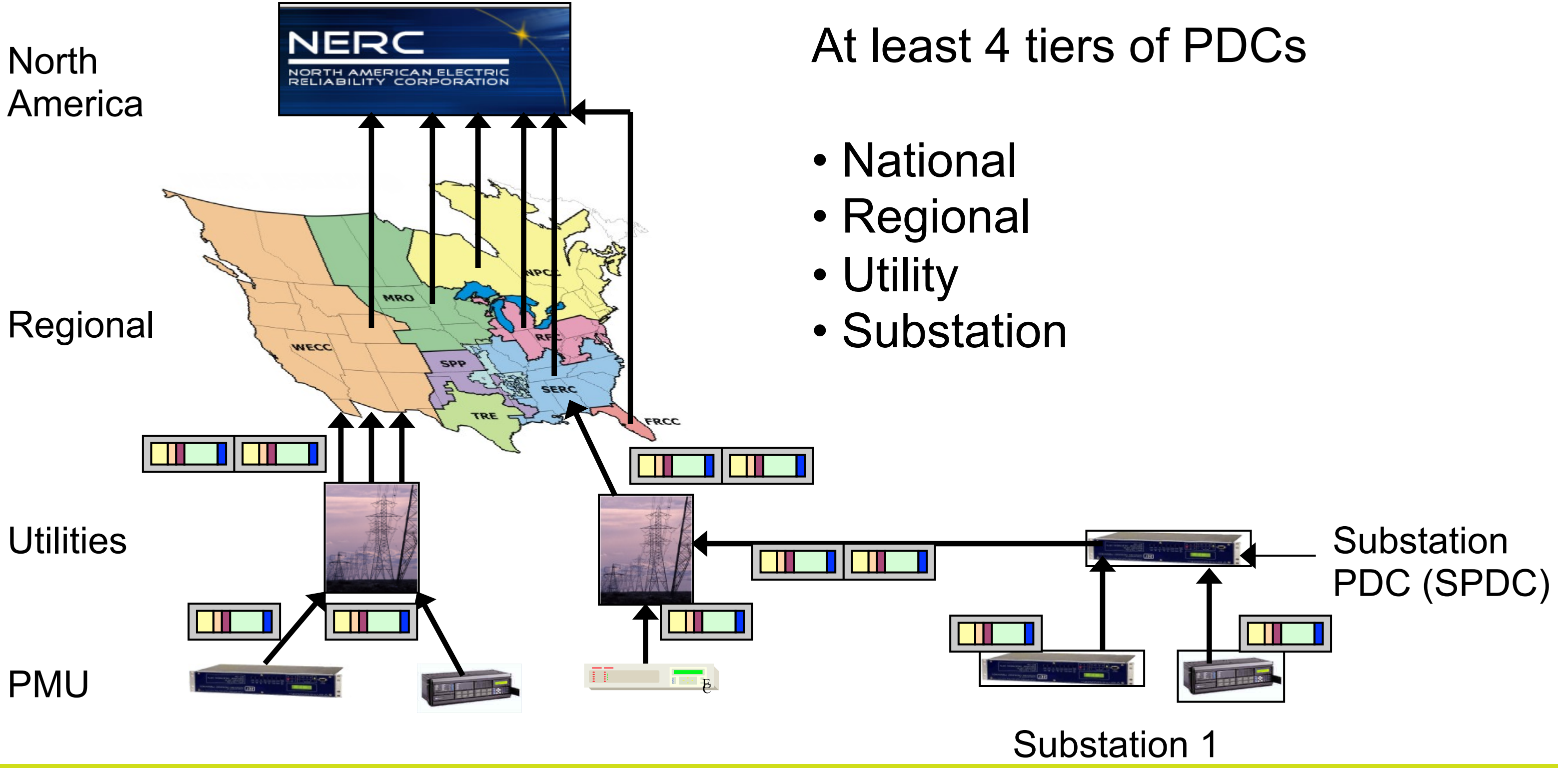
Group Participation:

- Who has PMUs being installed or installed?
- Who has more than one PDC in the deployment architecture chain?
- Who intends to use PMU information for automatic control decisions?
- Who knows about IEC 61850-90-5?

What is the impact of PDCs and Control

- What latency is introduced?
- What is the deployment considerations for security?

PMU and PDC Typical Exchange Architectures



At least 4 tiers of PDCs

- National
- Regional
- Utility
- Substation

Primary Purpose of PDCs

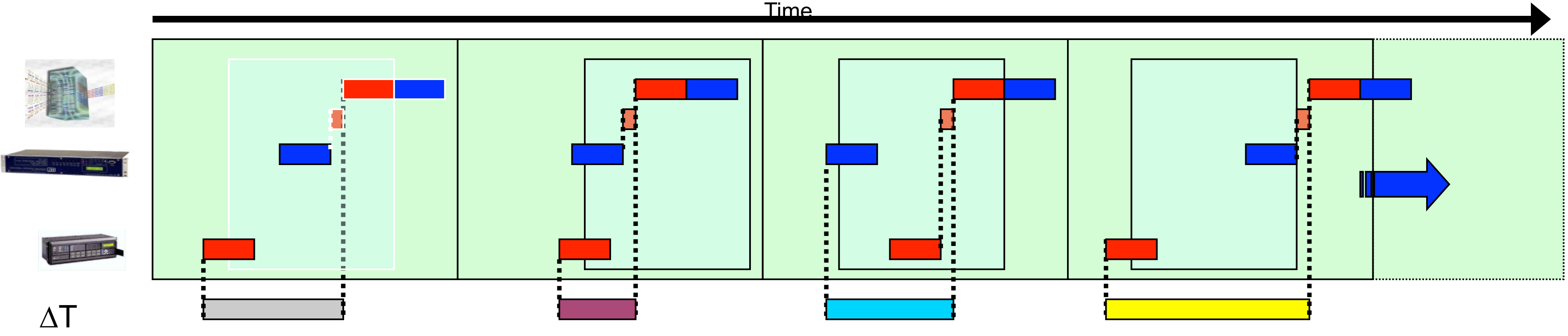
- PMUs have a limited number of consumers that can be supported*

    Most non-multicast stream PMUs are limited to 4 consuming applications.

- Provide Time-Alignment of multiple PMU streams for applications.

- Minimizing the number of streams that need to be consumed by the N+1 tier.

How PDC's perform time alignment



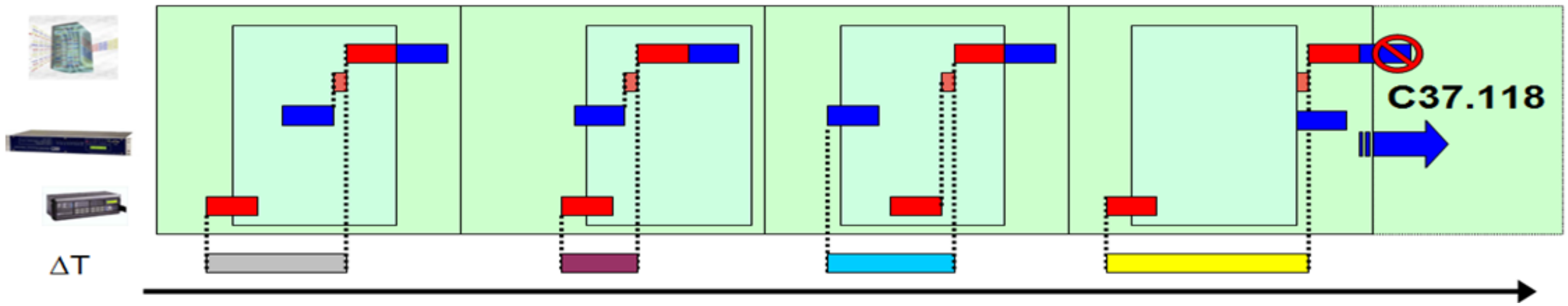
PDC Reporting will Jitter

General Guidance

$1/\text{Report Rate} > \Delta A_{max} + \Delta P$

- PMU Reporting (1/Report Rate)
- Time Alignment Delay (ΔA_{max})
- PDC Processing Delay (ΔP)

Need to avoid data "loss"

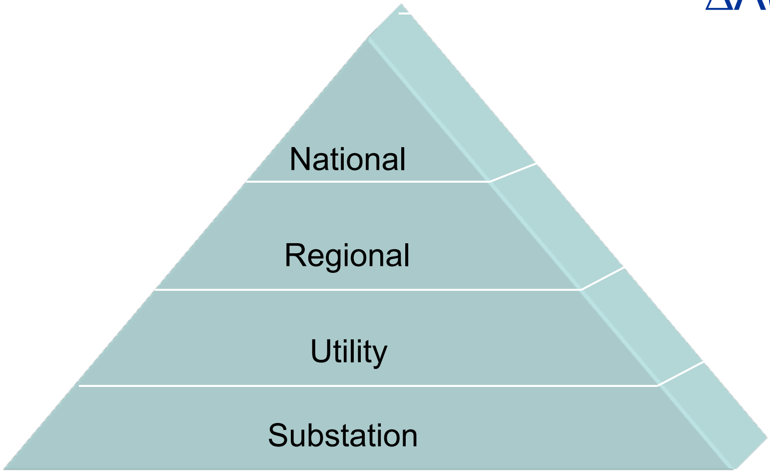


Time alignments and mechanisms need to be determined on a application by application basis (2 prevalent buffering/reporting algorithms):

- ΔA is small (slightly greater than reporting rate).
- ΔA is large (1 second typical).

Hierarchy and PDC impact on Operational Performance

(ΔA small)



ΔA(msec)	ΔP(msec)	Reporting Rate
43 + 5	10	16-17 (58 – 60 msec)
28 + 5	10	20-23 (43 – 50 msec)
14 + 5	10	30-35 (28 – 29 msec)
5	10	60-70 (14 – 16 msec)

Need to understand network utilization

What if ΔA is large?

- Re-emission Time (ΔE) is small (e.g. approaching 0)
  - Limited by Bandwidth of media
  - Decreases "average" latency
  - May have un-anticipated results to receiving applications
- ΔE is 1 second (e.g. same as ΔB)
  - Assume that reporting rate is equally distributed.
  - More likely to be tolerated by receiving applications

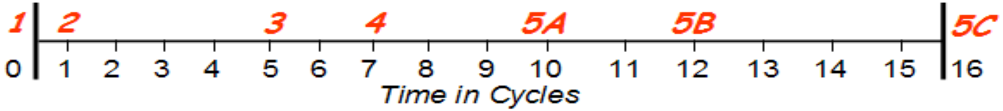
ΔE (T1) for 30 reports/second for 256 bytes/report is approximately: 30 msec

What would this do to visualization?

ΔE for 30 reports/second

Operations include control (e.g. Remedial Actions Schemes and Others)

A RAS Case Simulation



1 cycle = 16.7 milliseconds

	Time	Operational Events
Step *1*	@ 0 Cycle	3 Phase Fault on the Bus
Step *2*	@ 1 Cycle	Relay Processing time for trip signal to CBs
Step *3*	@ 5 Cycles	Open CBs for line/transformer out
Step *4*	@ 7 Cycles	RAS Logic Processing for trip signal to CBs to trip generators
Step *5A*	@ 10 Cycles	Open CBs associated with 12 generators (I Batch Mitigation)
Step *5B*	@ 12 Cycles	Open CBs associated with 4 generators (II Batch Mitigation)
Step *5C*	@ 16 Cycles	Open CBs associated with 2 generators (III Batch Mitigation)

Event Detection Fault Clearing: 5 Cycles

RAS Processing: 2 Cycles

Mitigation Generation Tripping / Load Shedding: 9 Cycles

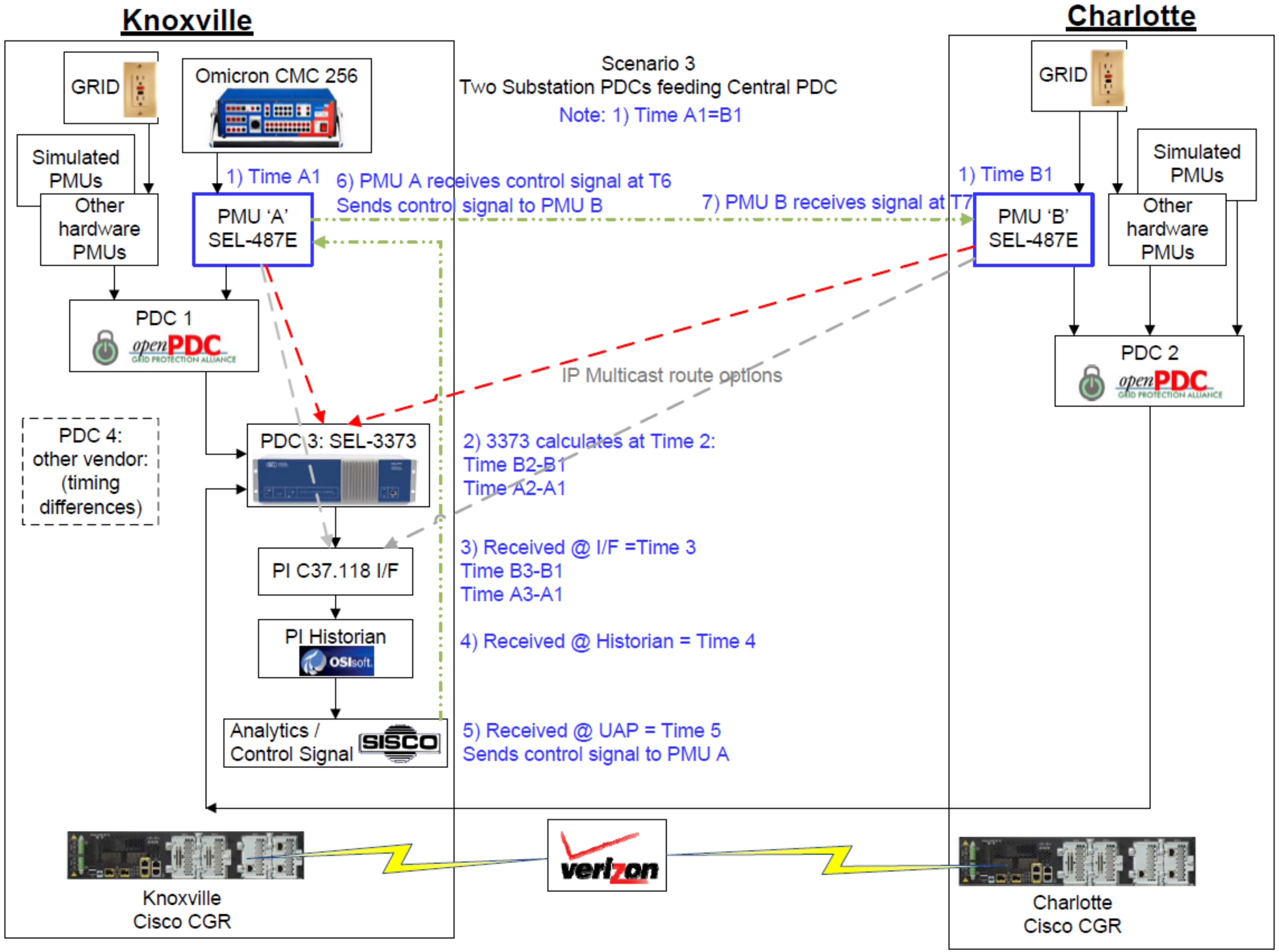
Total Elapsed Time: 16 Cycles

RAS Processing Target: 3 Cycles (50 msec)

Testing and understanding is key:

(Current thought process for research test architecture).

Being extended to have multiple PMU/PDC vendors.



Control issues: Events vs Streams

- Consider reporting a digital state in a synchrophasor stream 30 times/second.
  - This means that the transmission of a change of digital state is delayed by at least 30 msec. XX actually AT MOST 30 MS + PROCESSING TIME
- The implication of this is that this stream reporting rate is not useful for high-speed control/critical applications (e.g. RAS). In order to use streams for control, faster report rates are required if events are not implemented.
- Indicates the need for event driven messaging for digitals as well as streaming analogs.

Next steps after C37.118 Testing

- Evaluation of IEC 61850-90-5.
- Harmonization of synchrophasor measurements with CIM and 61850 model.

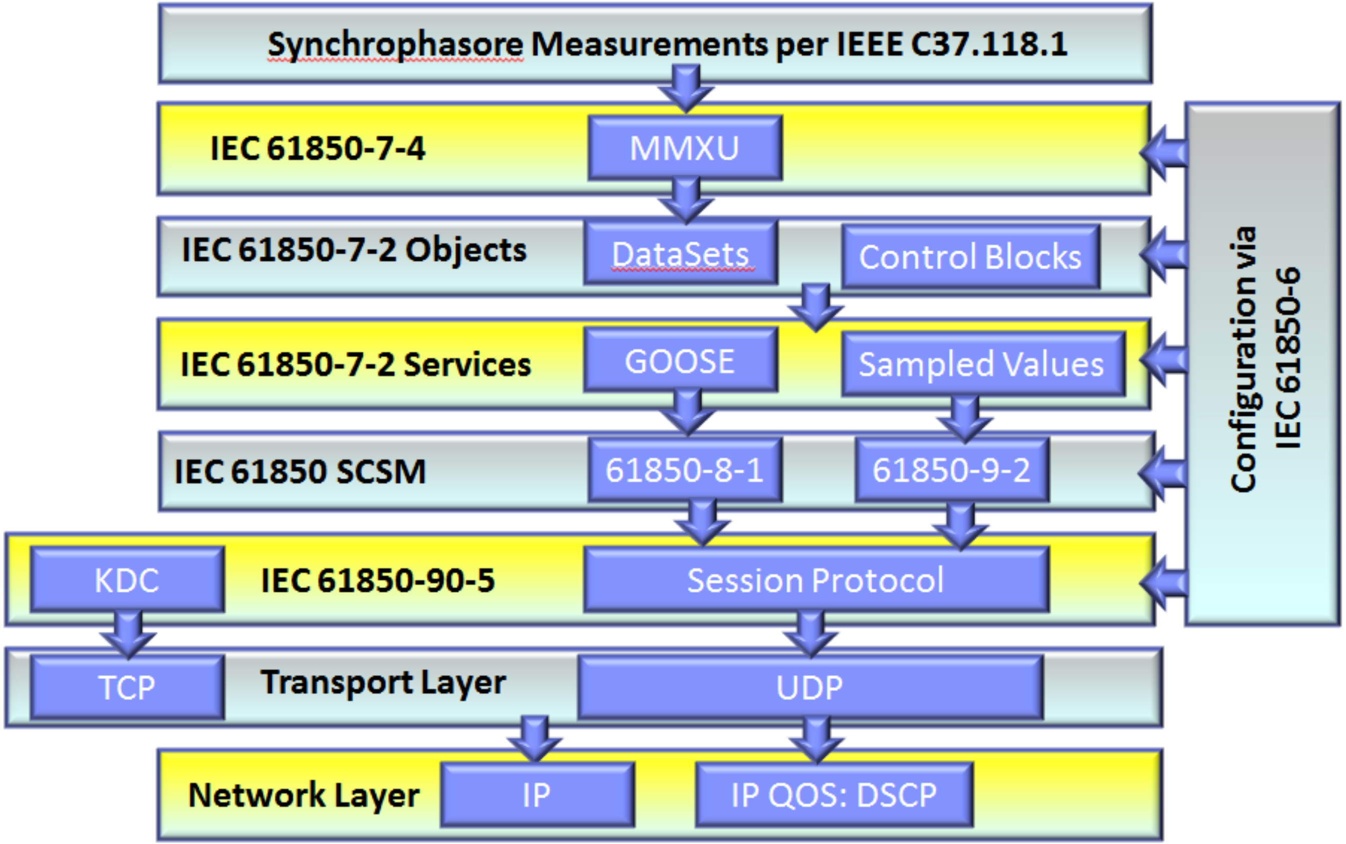
Comparison of C37.118.2, 61850, and 61850-90-5

Function	C37.118	IEC 61850 GOOSE and SV	IEC TR 61850-90-5
Streaming Protocol	Yes	Sampled Values is streaming GOOSE is event driven	
Rate of Measurement/Reporting	10 -30 samples/second	80-256 samples/cycle (4800 – 15360 samples/second)	10 – 15360
Natively Routable using IP	Yes	No. Must use bridged-routing (brouting)	Yes
Application Focus	Situational Awareness	Control (3 msec)	Control and Situational Awareness
Standard Addresses Security	No	Yes – Authentication (62351-6)	Yes – encryption and authentication
Communication profile fully specified	No	Yes	Yes
Measurement Specification for synchrophasors	Yes	No	Reference C37.118.1
Event Driven Capability	No	GOOSE	
Protocol is semantically driven (e.g. object oriented)	No	Yes	
Standardized configuration language	No	Yes	

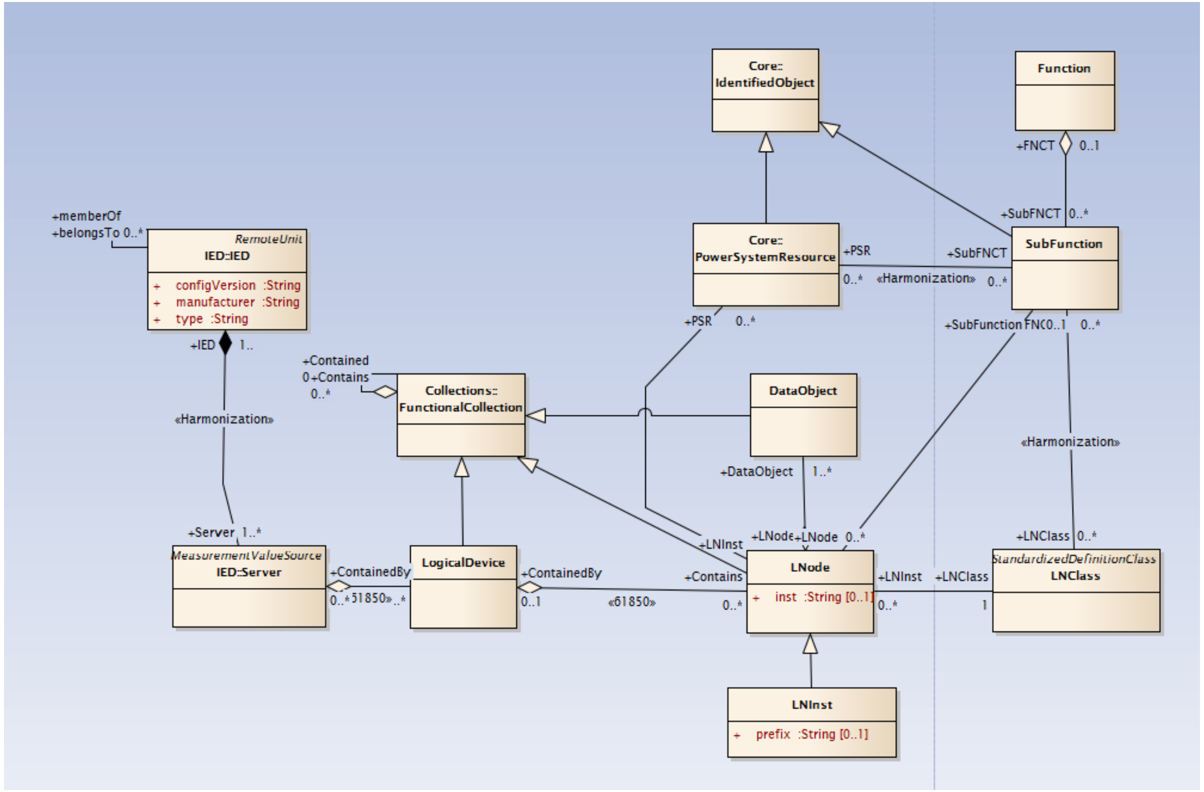
Required for Control

Required for Control

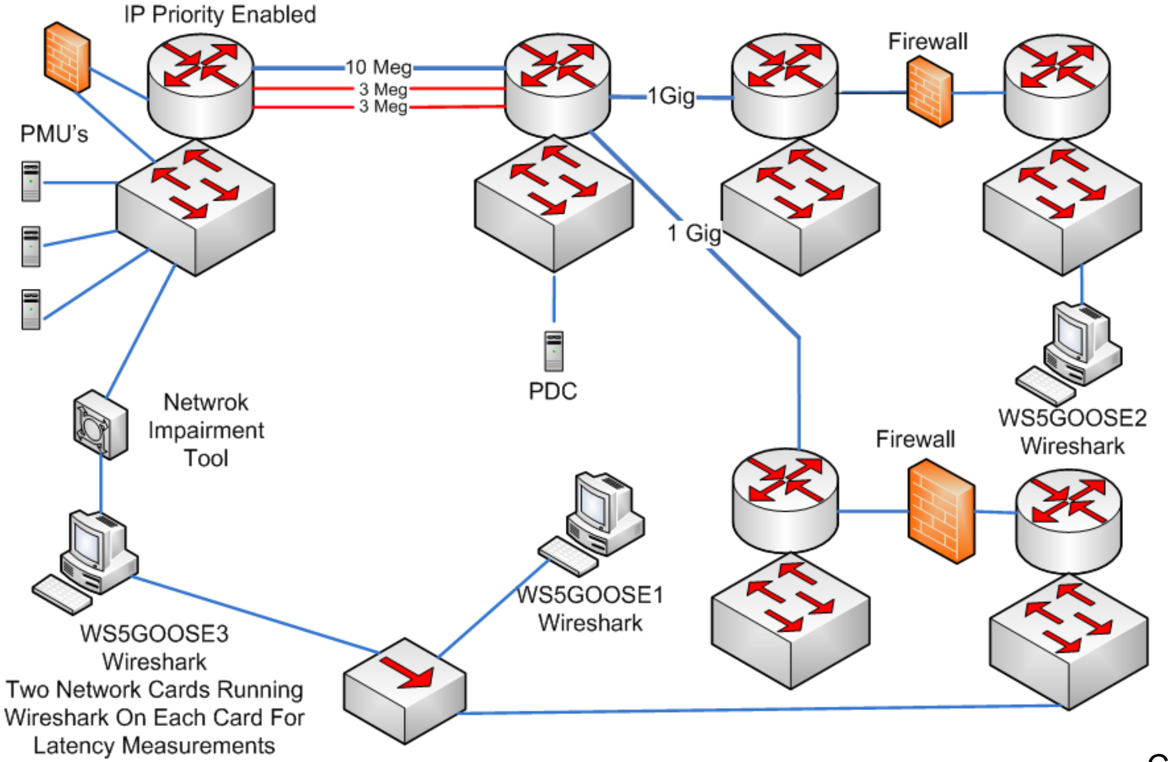
What 90-5 Looks like



How Synchrophasors integrate with CIM and 61850

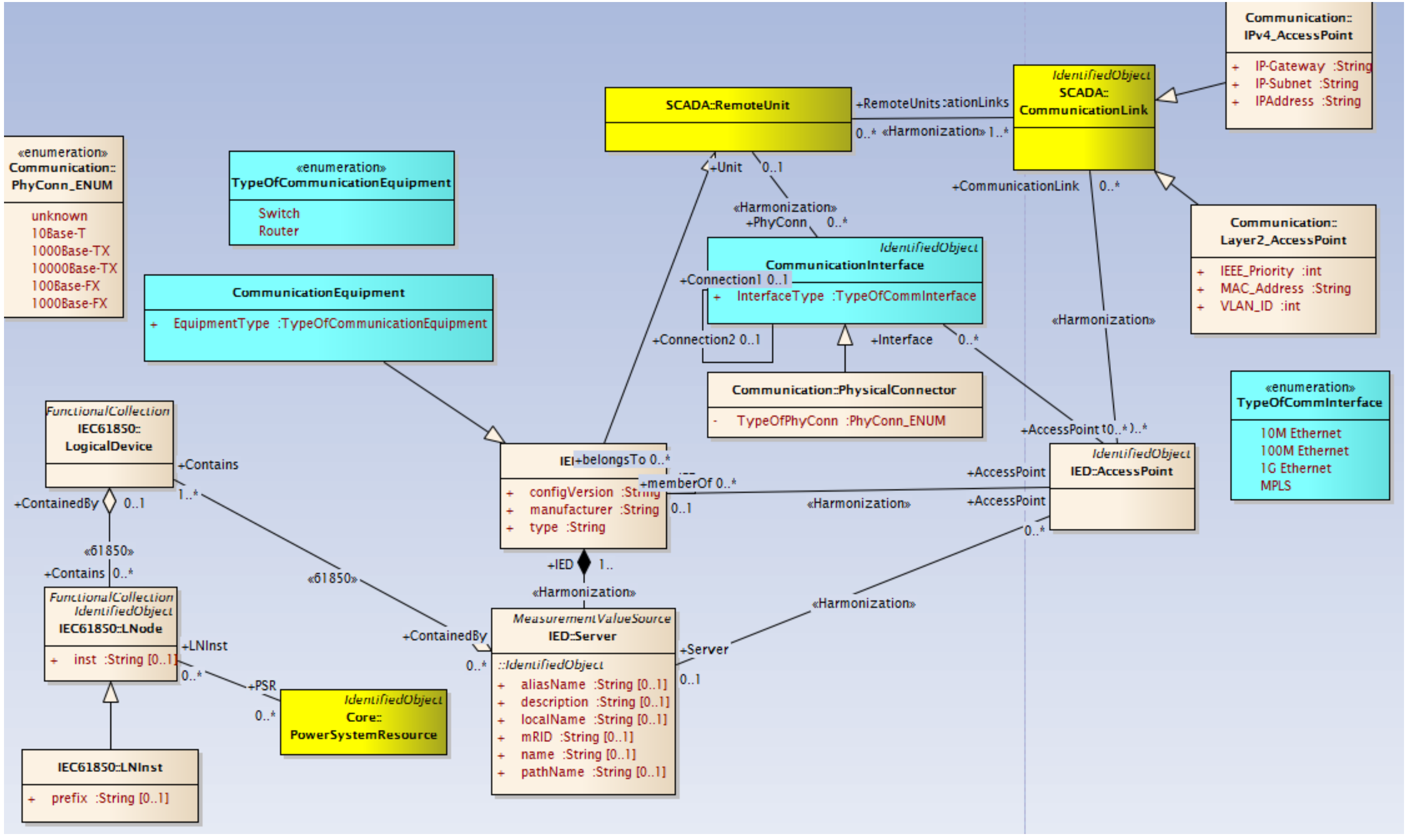


Security and appliance impact?



Courtesy of Pacific Gas and Electric

Combining CIM, 61850, and Comms

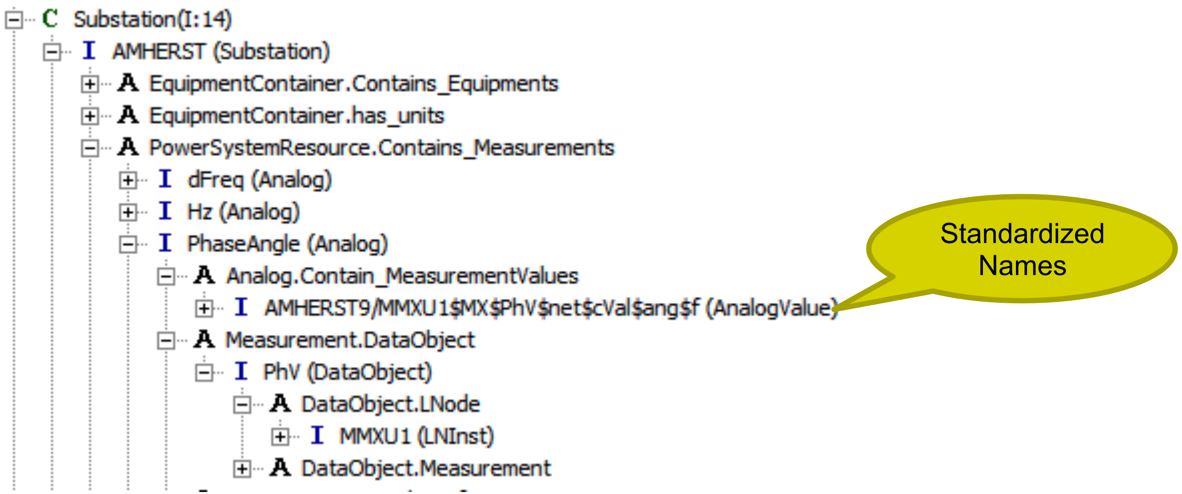


Impact on OSIsoft users

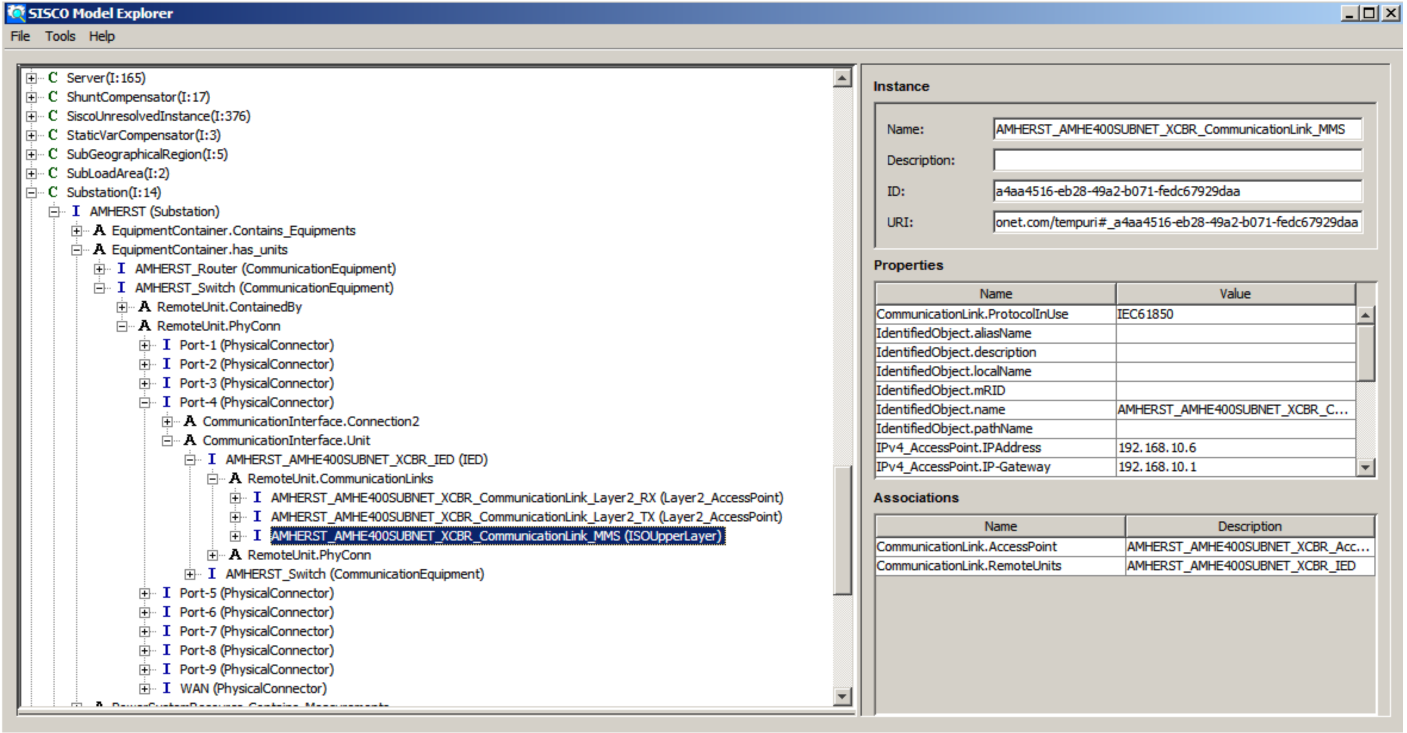
- New interface to support 90-5 for secure synchrophasor exchange.

- Modeling in AF for CIM+ other information.

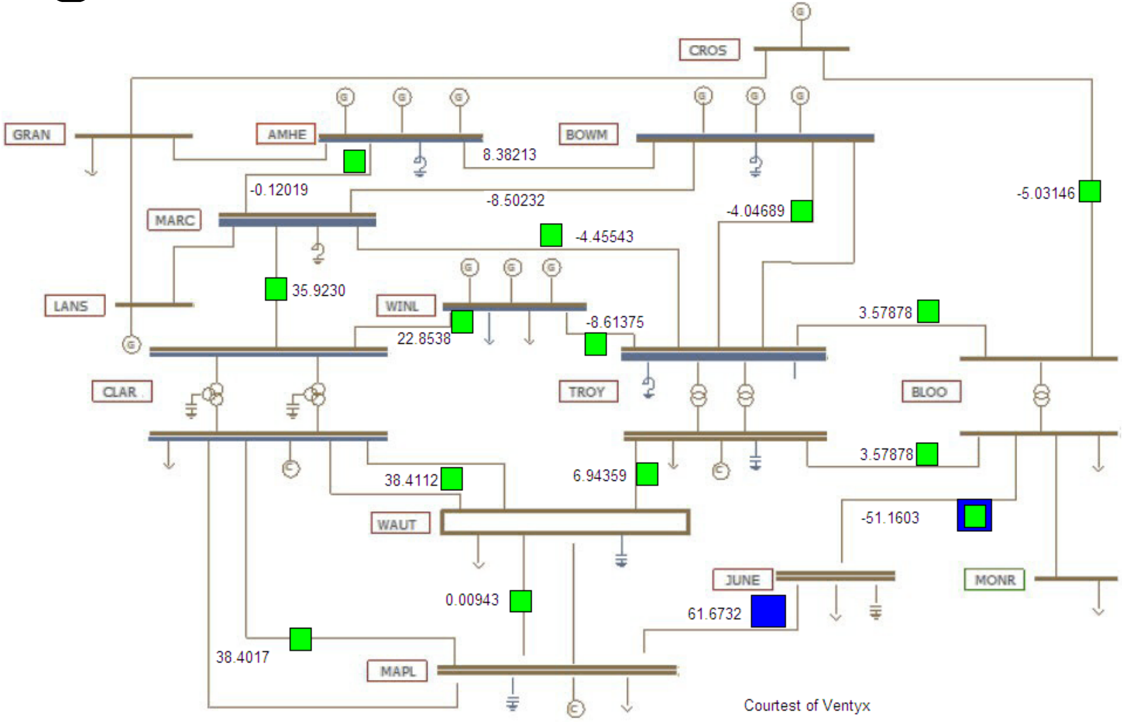
Synchrophasor, CIM, and 61850: in AF



CIM, 61850, and Comms if AF



Once in AF, can use the rest of OSIsoft Tooling for visualization and analysis



Courtest of Ventyx

THANK YOU

Brought to you by OSIsoft.