Interoperability Issues, Tests, and Practical Examples (PMU, PDC, SuperPDC)

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NASPI Meeting, October 16, 2012, Atlanta, GA

Pacific Gas and Electric Company®

QUANTA TECHNOLOGY

Interoperability Considerations

- Standards
  - Having standard(s) is required but not sufficient for interoperability.
  - Standard compliance doesn't guarantee interoperability
- Implementation Agreements
  - Clear Implementation Agreement(s) among various device developers and manufacturers are usually required to achieve interoperability
- Testing
  - Both standards and implementation agreements are subject to interpretation and may include options, choices, or configurations.
  - Only actual testing can verify interoperability between various devices/systems.
  - Testing often identifies the need (or desire) for improvements and enhancements, as well as feedback for improving standards and implementation agreements.
- Life-cycle management
  - Life-cycle management, asset utilization, and revision control are all considerations affected by interoperability
  - Device interoperability needs to support system life-cycle management and asset utilization (long-term system deployment roadmap to be supported)

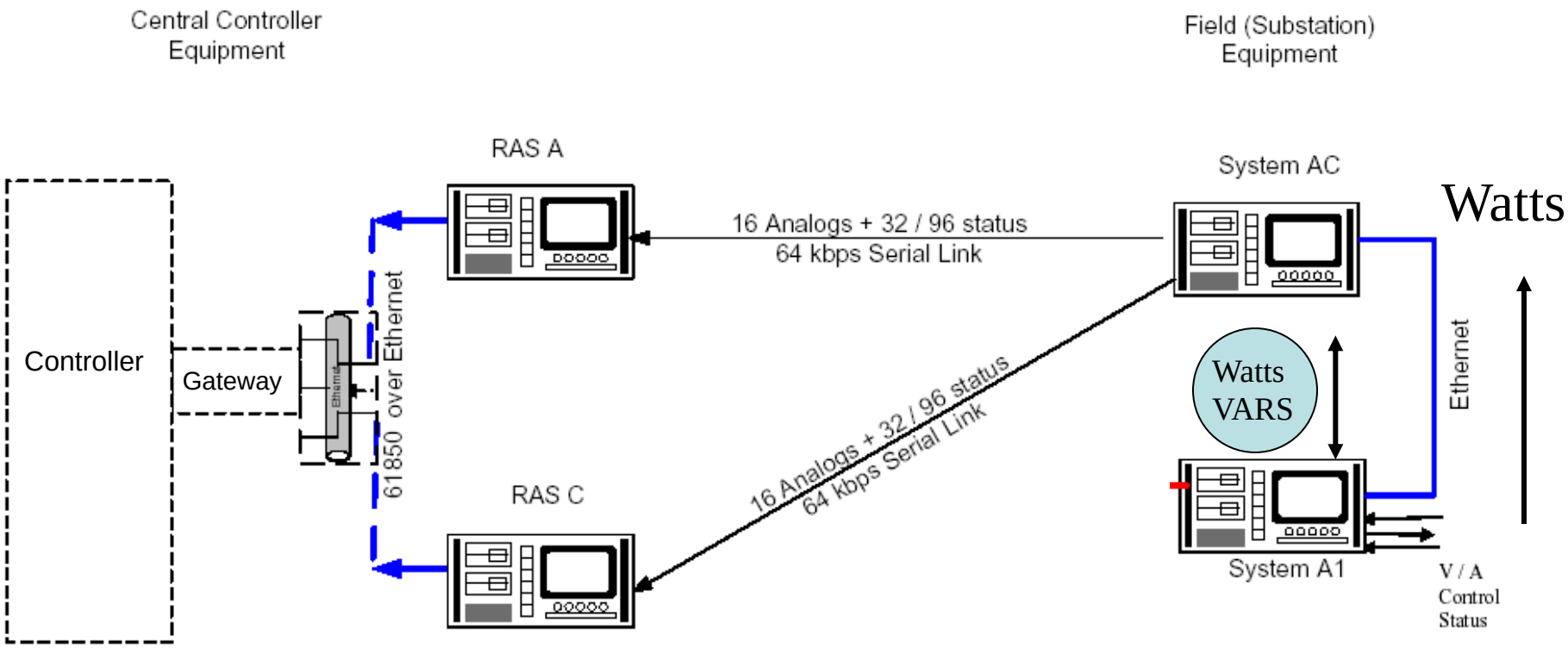
IEC 61850 Certification

- Benefits of conformance test before implementation?
  - Resolves interpretation differences
  - Early identification of non-conformances
  - Exact functionality of the protocol is identified
  - Multi-vendor solutions will have interoperability issues
  - New offerings will have bugs
  - Most manufacturers have missing pieces
- Conformance Test
  - Does implementation conform to the standard?
  - What is the behavior in error situations?
- Interoperability Test
  - Do the communication services provided by one device interoperate with other devices?
- Involves UCA-IUG Documents
  - QA Program
  - Accreditation program
  - Approved Test Procedures
- Requiring a Certified Product from a Vendor Means:
  - Vendor makes the investment as appraisal costs
  - Cost is spread over all sold licenses of the product
  - Early discovery of problems avoids dealing with unexpected behaviors during installation and over project life cycle
  - Vendor and User save dollars and time in Operation & Maintenance

IEC 61850 Certification does not address….

- Interoperability Test
  - ✓Does not cover application interoperability
  - ✓Burden is on the User – Include in your Spec.
- Stress and Performance Test
  - ✓Identifies boundary limits for the device
  - ✓Establishes whether the device meets the performance requirements for the application
- Reliability, Redundancy, Failure Modes and Contingencies

Example – Hybrid GOOSE and Serial Communication



Use of high speed serial links (Up to T1 level) and Interface with GOOSE Messaging

Benefits

- Replacement of wires with communication
  - Costs
  - Improved flexibility
  - Reduced commissioning time
  - Improved monitoring
  - Ease of use with optical sensor technology
  - Prevents mixing DC circuits
  - Ease of applications when I/Os are limited
- Besides SCADA Data
  - Superior Asset Management means
  - Condition monitoring of primary equipment
  - Power Quality Information
- Self description and configuration language
  - Verify the configuration of the system
  - Automatically create test patterns
- Ease of Applications with Synchronized phasors
  - Data sharing over large geographical grids
    - ✓ Neighboring systems (subject to Cyber security)
  - Phasor Data Concentrators (PDC)

- When implemented properly…
- **Self monitoring capability**
  - Constant real-time status of control point communications, with alarming by IEDs for failure anywhere from the source IED intelligence to the implementing IED.
- **Fits with "overlapping** zones of monitoring" approach to having a maintenance program.
  - Critical for Protection
  - Vital for System Integrity Protection Schemes (SIPS) and Wide-area Remedial Actions Schemes (RAS)
- **Better than** many or most existing schemes in this way
- **Timing and loss rate** monitoring can be programmed

Design Requirements/Criteria

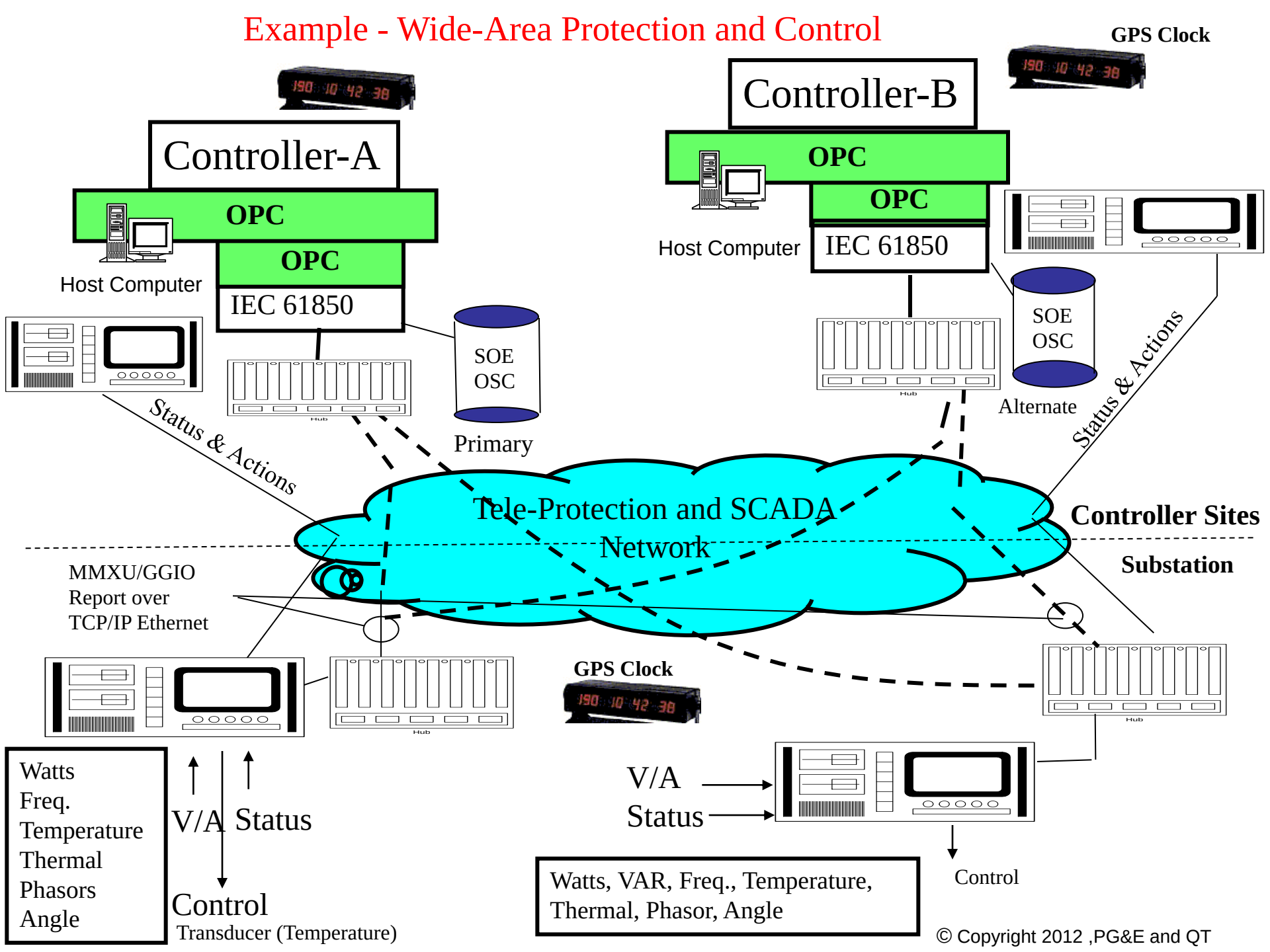
Example – typical for the overall system

1. High availability/reliability (>99.995)
2. Automatic self diagnostics
3. Easy to maintain
4. Throughput time < 25 ms
   - Hierarchical structure
   - Detection, transmission, central processing, and execution
5. Full Redundancy (no single point of failure)
6. Controllers-Triple Modular Redundant- (2 out of three voting scheme)
7. Compliance with regulations

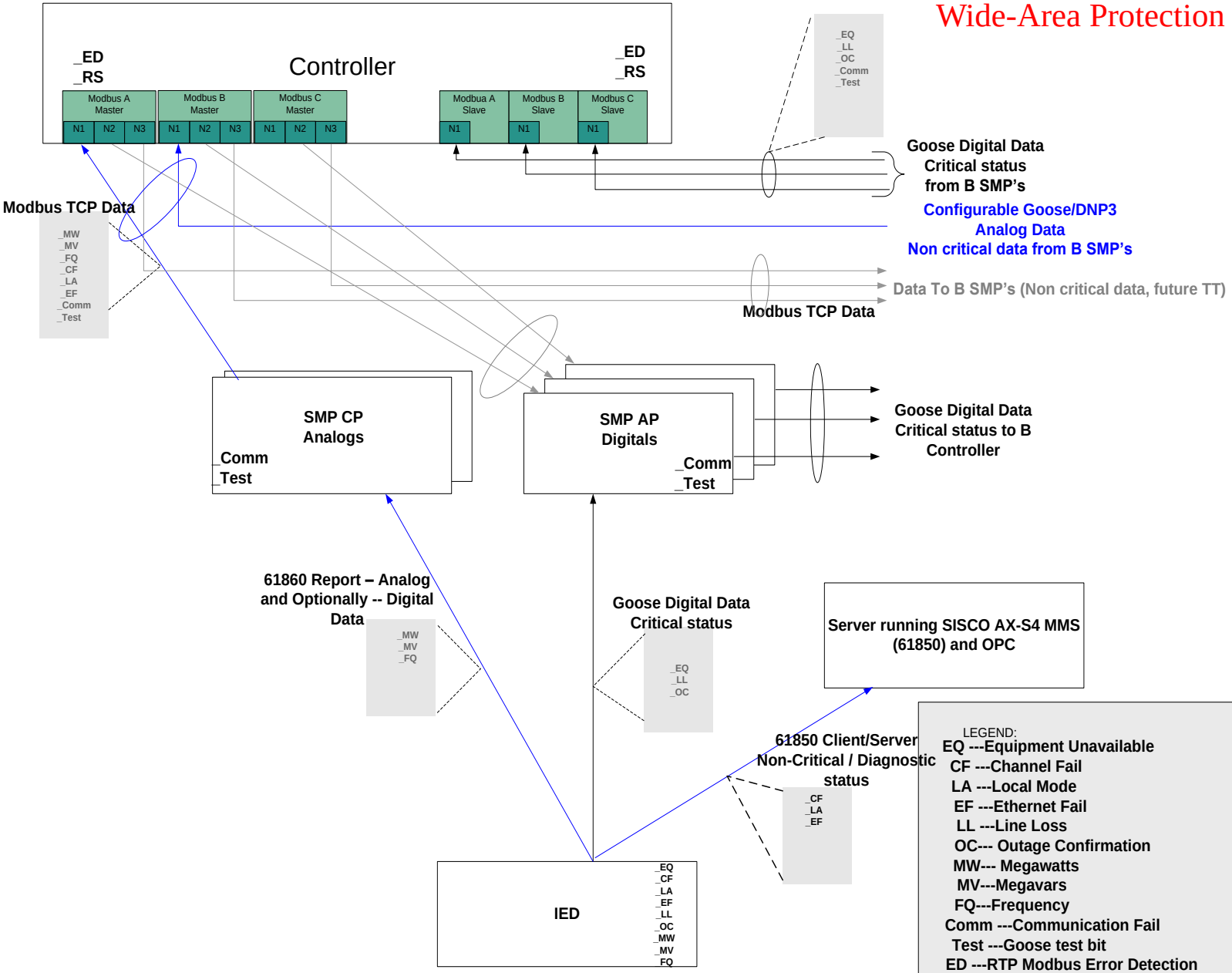
Messaged versus Hardwired

- Advantages:
  - Replace local control wiring with network communications
  - No need for periodic testing (devices communicate continuously)
  - Minimizes hardware installation
  - Saves space
  - Provides almost endless expansion capabilities
  - No need to update wiring diagrams
  - No contacts, debounce filtering, not prone to noise
- Drawbacks:
  - Signal Propagation delay – May be variable
  - Need robust setting tracking mechanism (version control)

Example - Wide-Area Protection and Control



Example
Wide-Area Protection and control



LEGEND:
EQ ---Equipment Unavailable
CF ---Channel Fail
LA ---Local Mode
EF ---Ethernet Fail
LL ---Line Loss
OC--- Outage Confirmation
MW--- Megawatts
MV---Megavars
FQ---Frequency
Comm ---Communication Fail
Test ---Goose test bit
ED ---RTP Modbus Error Detection
RS ---RTP Modbus Register Status
N1 ---Modbus Node 1
N2 ---Modbus Node 2
N3---Modbus Node 3

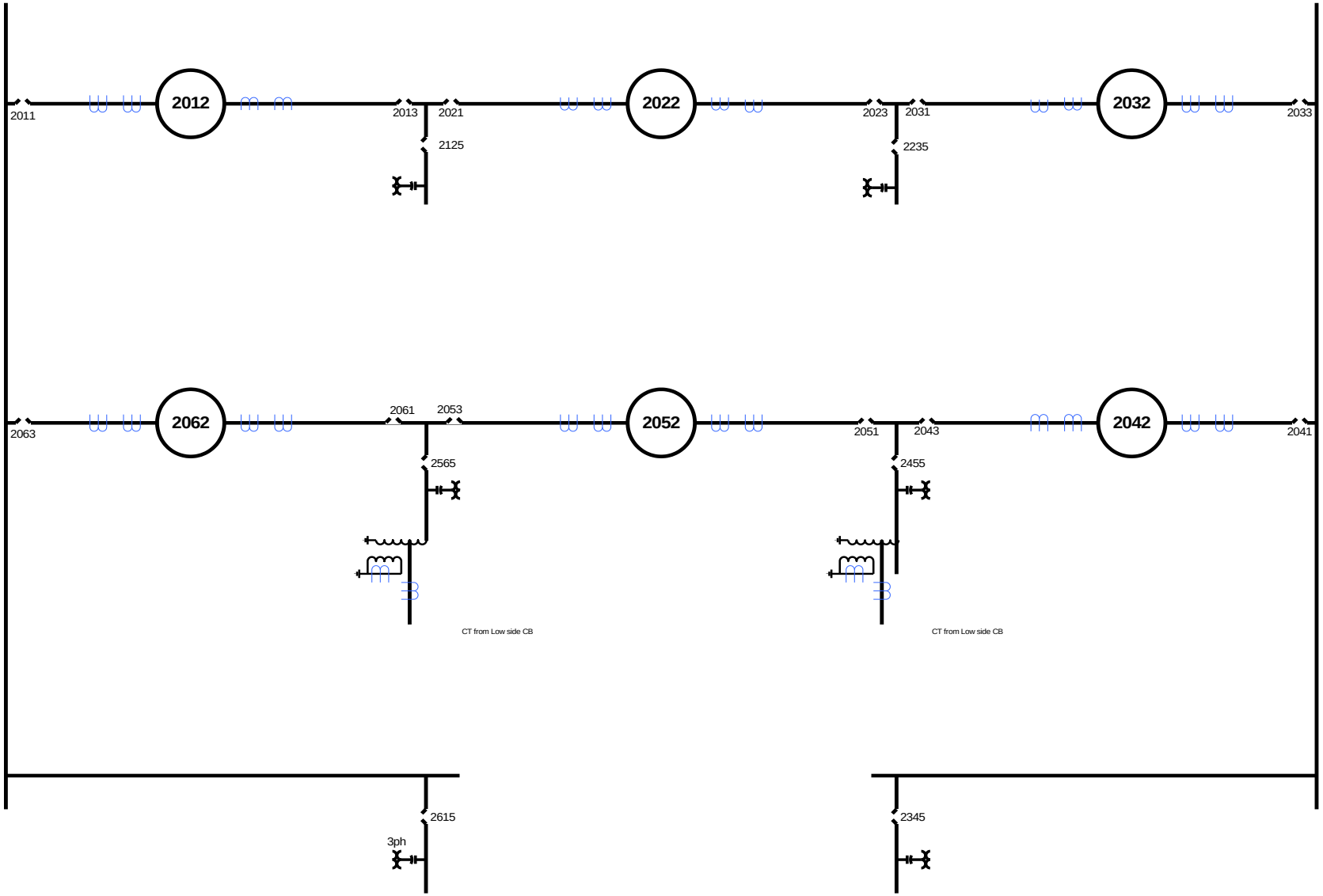
Benefits of using New Emerging Technologies

- Condition based maintenance (reduction of human errors)
- Performance statistics
- Tools for Clearance analysis and tracking
- Database historian can be leveraged to provide maintenance and testing reports.
- Flexibility in Engineering, Design, and Asset Utilization
- Access operational and non-operational data for many business purposes
- Sequence of Events (SOE) Records-Oscillography
- Trending data
- Help in system restoration
- Automated reports/charts generation
- Ability to record and playback actual events

Why focus on Ethernet control?

- Deployment of advancing IT technology elsewhere in the enterprise – Can we leverage the investment?
- Industrial activity
  - Ethernet LANs for control used in process control
  - Modbus RTU on TCP
  - Ethernet IP – DeviceNet in Ethernet format.
  - Lots of low-cost hardware is breaking down old focus on "non-deterministic" network – not as bad as feared!
  - Sub-microsecond accuracy time sync over Ethernet (IEEE 1588)
- Substation LANs
  - DNP3 over TCP; Modbus TCP
  - UCA and IEC 61850 emerging (more later)

Example: RING or Breaker and Half Bus Messaging



What is Needed? - Tools

	REMOTE I/O--RING BUS	CB-2012	Set A Line - 1	CB-2022	Set A - XFMR	CB - 2032	Set A Line 3
Device / Output	DEVICE:	1	2	3	4	5	6
1.1	BFT BLOCK AUTO (86BF)	**RO:1**		RI:3			
1.3	BFT TO DTT	**RO:3**	RI:2				
1.2	HS 1ONLY INTLK TO LEFT	**RO:2**					
1.4	HS 1ONLY INTLK TO RIGHT	**RO:4**		RI:4			
1.5	CBM CONTROL	**RO:5**		RI:6			
1.7	CBM LT13 TO LEFT	**RO:7**					
1.8	CBM LT14 TO RIGHT	**RO:8**	RI:9	RI:9			
1.12	52A 20n2	**RO:12**		RI:11			
2.8	STUB BUS STAT	RI:5	**RO:8**	RI:10			
2.15	REMOTE BLK CLOSE	RI:15	**RO:15**	RI:16			
3.1	BFT BLOCK AUTO (86BF)	RI:1		**RO:1**		RI:3	
3.3	BFT TO DTT		RI:1	**RO:3**			
3.2	HS 1ONLY INTLK TO LEFT	RI:2		**RO:2**			
3.4	HS 1ONLY INTLK TO RIGHT			**RO:4**		RI:4	
3.5	CBM CONTROL	RI:7		**RO:5**		RI:6	
3.7	CBM LT13 TO LEFT	RI:8	RI:8	**RO:7**			
3.8	CBM LT14 TO RIGHT			**RO:8**	RI:9	RI:9	
3.12	52A 20n2	RI:12		**RO:12**		RI:11	

What is needed?

- Adequate training of engineers and practitioners
- Adoption to existing substation automation concepts and changes in the specification and design process
- Conformance Certification of Devices to IEC 61850
- The protection engineers need to prepare for the changed specification and design process
- Tools Industry Participation is Key:
  - Application Development
  - Ddocumentation of engineering desig – Substitues for Wiring and Schematics
  - Mapping
  - Performance Tracking
  - IP Address Standards and Management - Over Project Life Cycle
    - ✓ Ease of expansions
  - Configuration and testing
  - Troubleshooting
  - Maintenance
- Basic understanding of
  - The engineering approach with the use of the configuration language
  - The concepts of the object models and the basic communication services
  - The Ethernet technology with switches and priority tagging

What is Needed: Process Change

- Roll out for substation automation and Protection interlocking
- Top down process for specification and design
- Specification shall concentrate on
  - Functionality and data to be communicated
  - Performance and availability requirements
- Role of system integrator
  - Roles need to be properly defined
  - Responsible for performance and behavior of the overall system
  - Cooperation between user and manufacturer is important

Summary Conclusion

- Balancing Wire vs. Messaging
  - Know your application
  - Minimize logic variations between bus configurations
- Challenges and Opportunities - Bottom line:
  - Requires Teamwork with IT, Automation, and SCADA / EMS groups
  - Requires Acceptance by Management and Operators
  - Automating the system to meet the challenges of 21st century & reliable energy delivery
  - Real-time system prognosis and adaptive protection and controls
  - Reduce Down time
  - Easily adaptable to advancing technology – Ease of upgrade
  - Saving time & Smart Investment - $$$
  - Tools – User input is needed
- Real benefits
  - Innovative protection & control integration and automation solutions
- Internal Challenges and solutions
  - Internal:
    - ✓ Develop a migration path
    - ✓ Widespread rollout vs. spot upgrade
    - ✓ Standards, Training, Management Leadership support, In-house tools
    - ✓ When opportunity knocks, follow the blue print
  - Externals:
    - ✓ Industry collaborations for well defined standards
    - ✓ Work with vendors to develop features, enhance capability, tools, training

IEC 61850 – Process Level Mappings

- Get rid of most switchyard wiring.
- Streams of sampled values of voltages and currents multiplexed on few Ethernet fibers.
- Status and samples come from switchyard; control and time signals goes out into the yard
- Wiring losses and burdens are cut.
- EMI is eliminated.
- New signals can be added without new wiring to control house.

Interoperability Test – PMU to PDC Communications

- Synchrophasor data transport using IEC 61850-90-5 – streaming data:
  - PMU to Substation PDC
  - Substation PDC to Super PDC
  - PMU to Super PDC
  - Comparison with IEEE C37.118 UDP
- Communicating configuration data
- Mixed protocol – a PDC receiving IEC61850-90-5 and transmitting in IEEE C37.118.2-2011 UDP
- Impact of timing signals (e.g., IEEE 1588 v2 with power profile C37.238-2011)
- Layered testing
  - Can the receiving device parse the received data (protocol)
  - Is the received data correctly understood / interpreted (format)
  - Is the received data correct or corrupted – and consequences (data quality)
    - E.g., misunderstood time-stamp – and what will happen to the data (lost or saved or flagged)

Examples: Comparison of Data Transmission using C37.118 UDP and IEC 61850-90-5 Unicast and Multicast

Set-up at PG&E Proof of Concept (POC) Test facility:

- Two PMUs, labeled 5PMU1 and 5PMU6 see the same voltage and current information
  - 5PMU1 – transmits using C37.118 through a substation PDC to a SuperPDC (SPDC)
  - 5PMU6 – transmits using 61850-90-5 directly to the SPDC
- 1 ASDU / Frame – One-to-one relationship between frame and data units
  - Data unit is same as message size, i.e., 4300 bytes
  - Reminder: ASDU – Application Service Data Units
  - Can also set up to include multiple data units (ASDU) per frame - To allow repeated data to protect against loss of data (address missing data). Not shown in this presentation.
- PMUs are streaming P Class data at 120 records (frames) per seconds
- Interval of tests is 10 second (1200 records / seconds)

Test Setup Progression – Using IEC 61850-90-5

Test 1 – Test Messages Transmitted By PMU to OpenPDC

Test 4 – Test On Isolated POC Lab Ethernet Switches With VLAN

Test 5 – Test On Single Subnet With Router Connected

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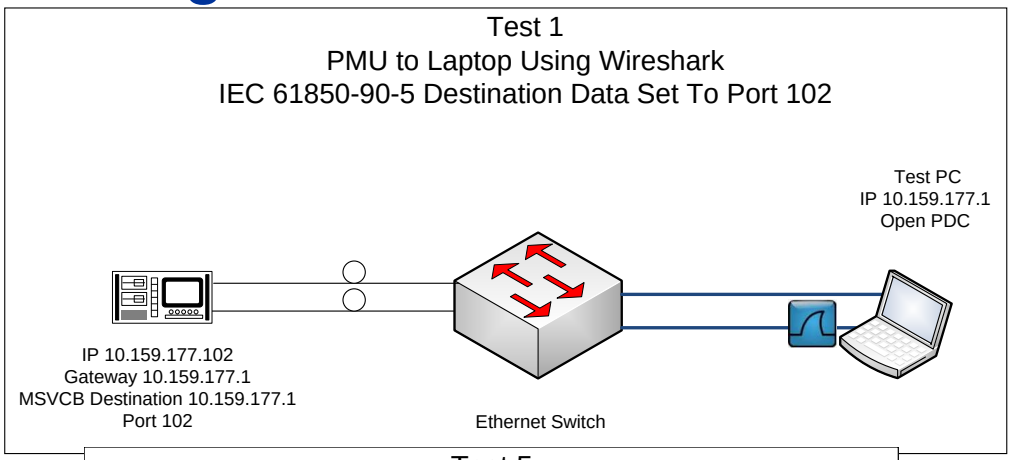
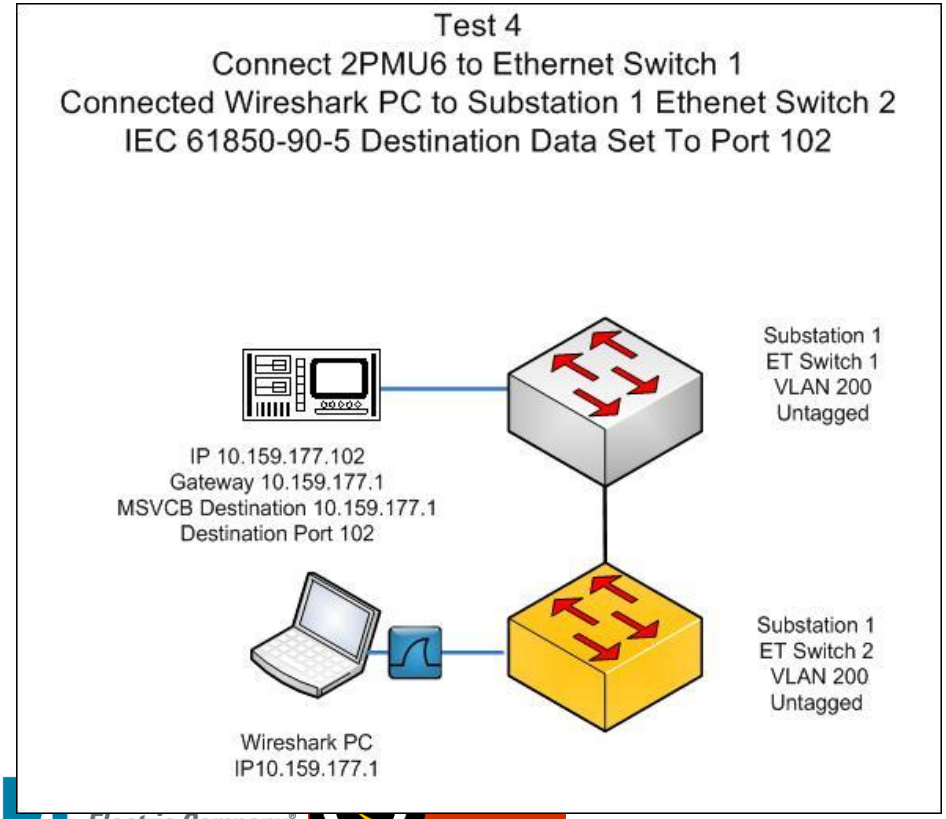
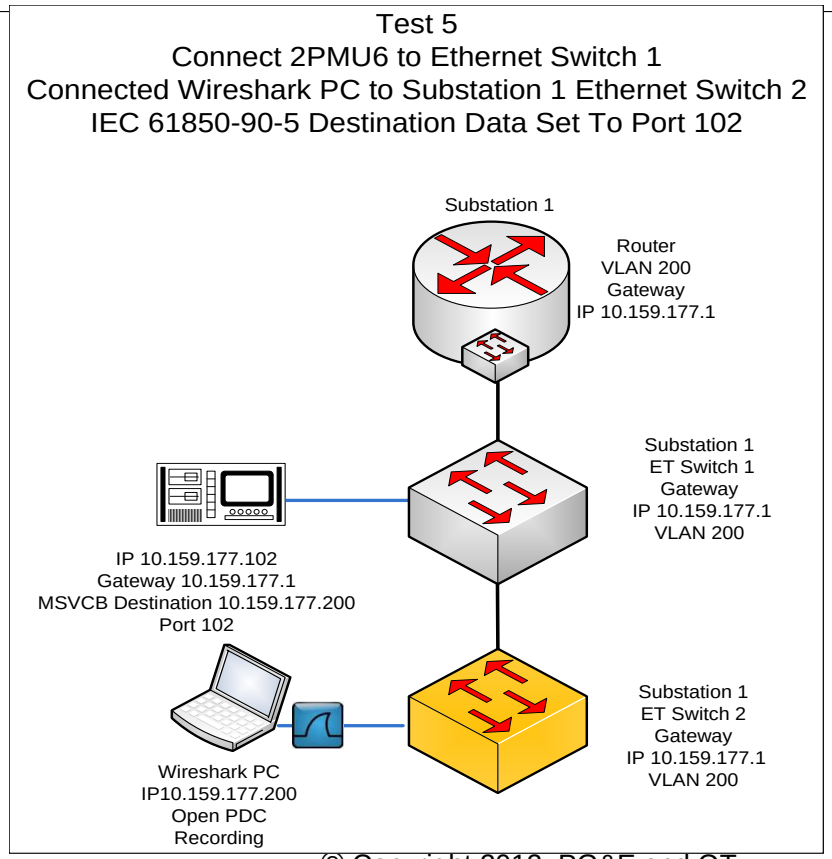


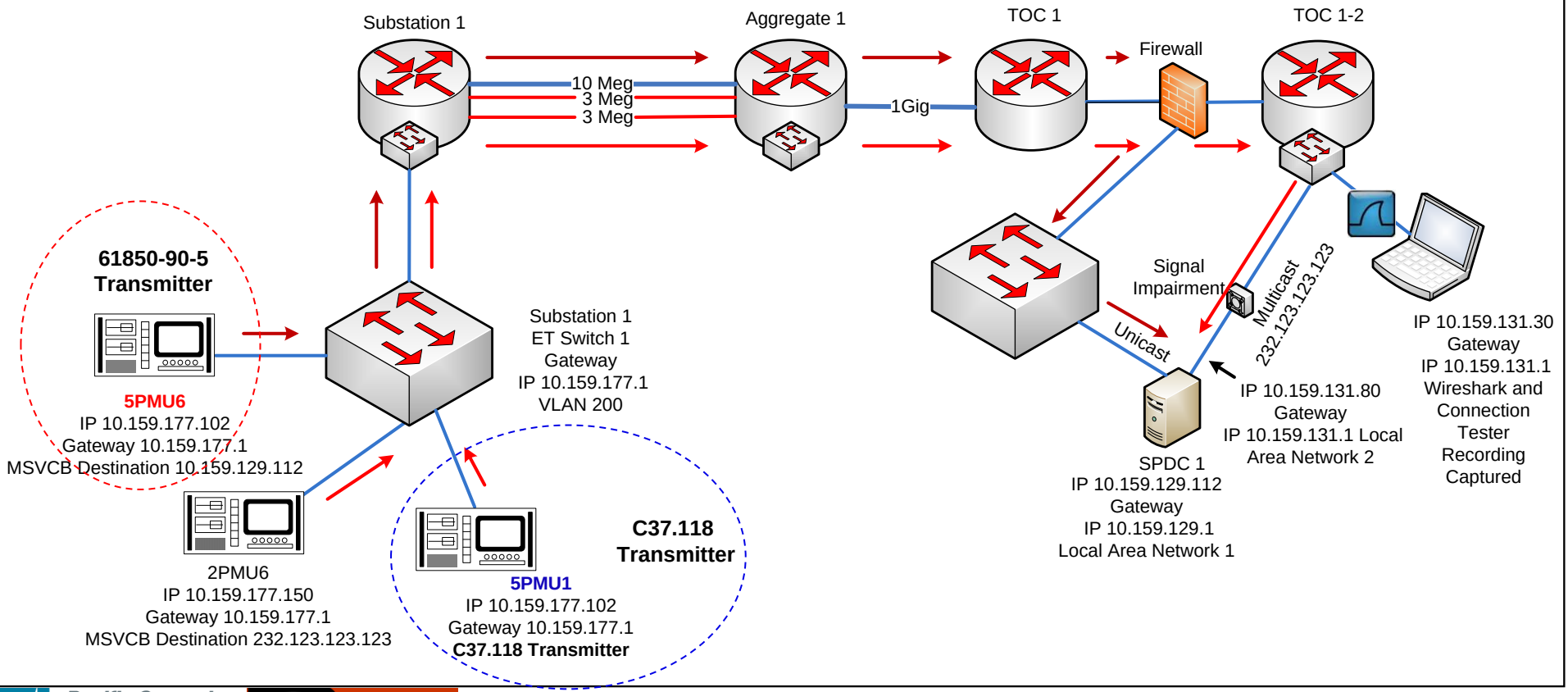




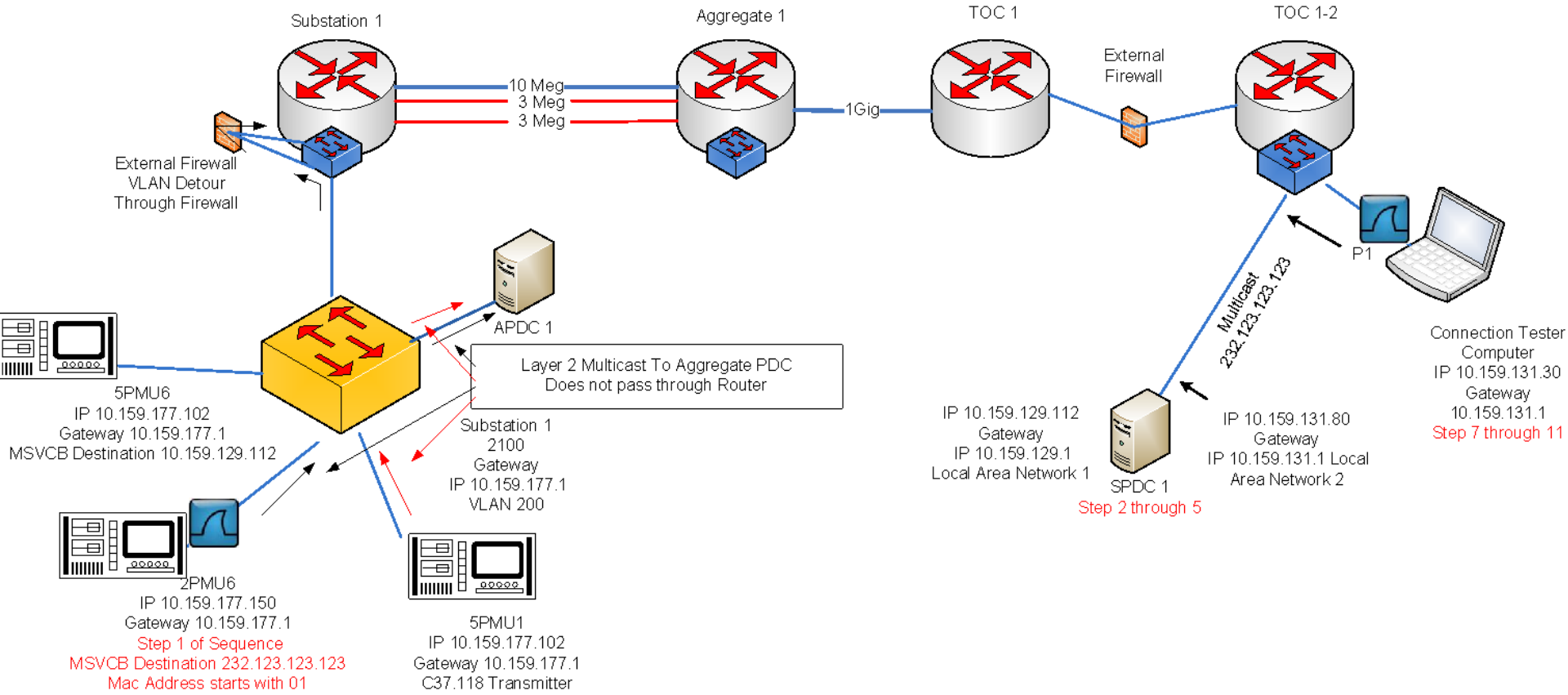
Test Setup Progression

- Unicast and Multicast between PMUs and Test PC
- IEC 61850-90-5 Destination Data Set To Port 102
- **5PMU1** – transmits using C37.118 through a substation PDC to a SuperPDC (SPDC)
- **5PMU6** – transmits using 61850-90-5 directly to the SPDC

Test 13 - Unicast and Multicast To SPDC Through Firewall



Multicast Between Field and Central Location



Interoperability Tests – Summary of the Findings

- A collaborative testing environment is a significant asset
- Various interpretations of standards and implementation agreements
  - Quality and status flags – limited implementation in some cases
- Different challenges for streamed data (e.g., synchrophasor measurements) and one-time data (e.g., status, control, config data)
- Unicast and multicast implementations
  - Varying support levels for routers, switches, and firewalls within the data path
- Impact of security features on interoperability and testing
  - Access to devices for configuration
  - IGMP 3.0 support
- Awareness of other system factors such as operating systems or communications stacks settings and limitations.
  - Example, UDP and TCP buffer sizes.
- Tools, tools, tools …
  - The need for efficient configuration and testing tools to accelerate and streamline interoperability (and other) tests.