Florida Electric Cooperatives Association

The Power of Human Connections©

Getting to Know the IEC 61850 Family

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Florida Electric Cooperatives Association – June 9, 2015

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What I hope you get out of this talk

For the technologies defined by IEC 61850:

- A basic understanding of what they are
- How all of the pieces work together
- Potential applications in your system

Why a new protocol?
What problem was it designed to solve?

- Handle all substation data and communications

- Data
  - Replace IED-specific point lists with standard data definitions
  - Exchange “real time” data between IEDs
- Movement of the Data
  - Replace terminal-to-terminal wiring and serial comms with a high speed communication network
- Automation
  - Provide a “platform”
- Ancillary services
  - Configuration, testing, protection, control, environmental, etc.

In essence: Use substation digital technology to the max!

How this talk will go

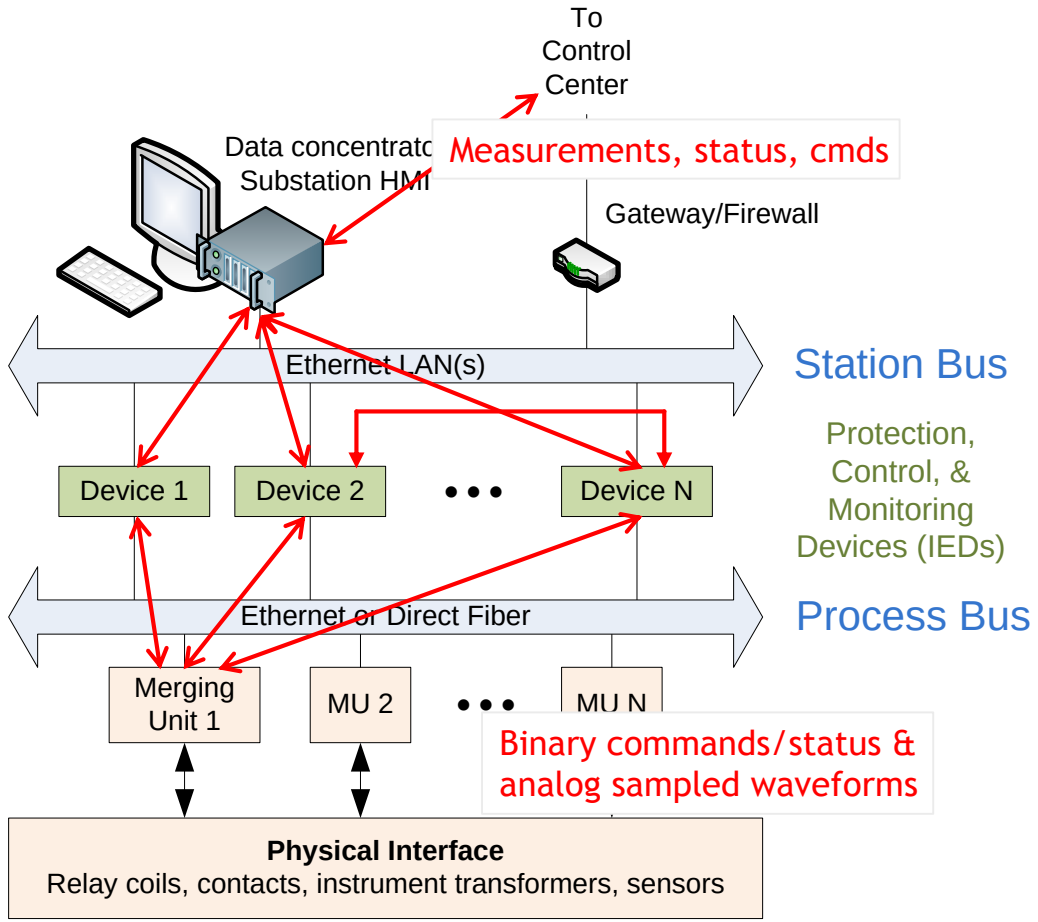
- All the features of the standard – big picture
- Data transfer
- What does the data look like?
- Configuration
- Network communication essentials
- Process Bus alternatives
- GOOSE Demo

Much more than a “Protocol”

Big Picture of this “family of standards”

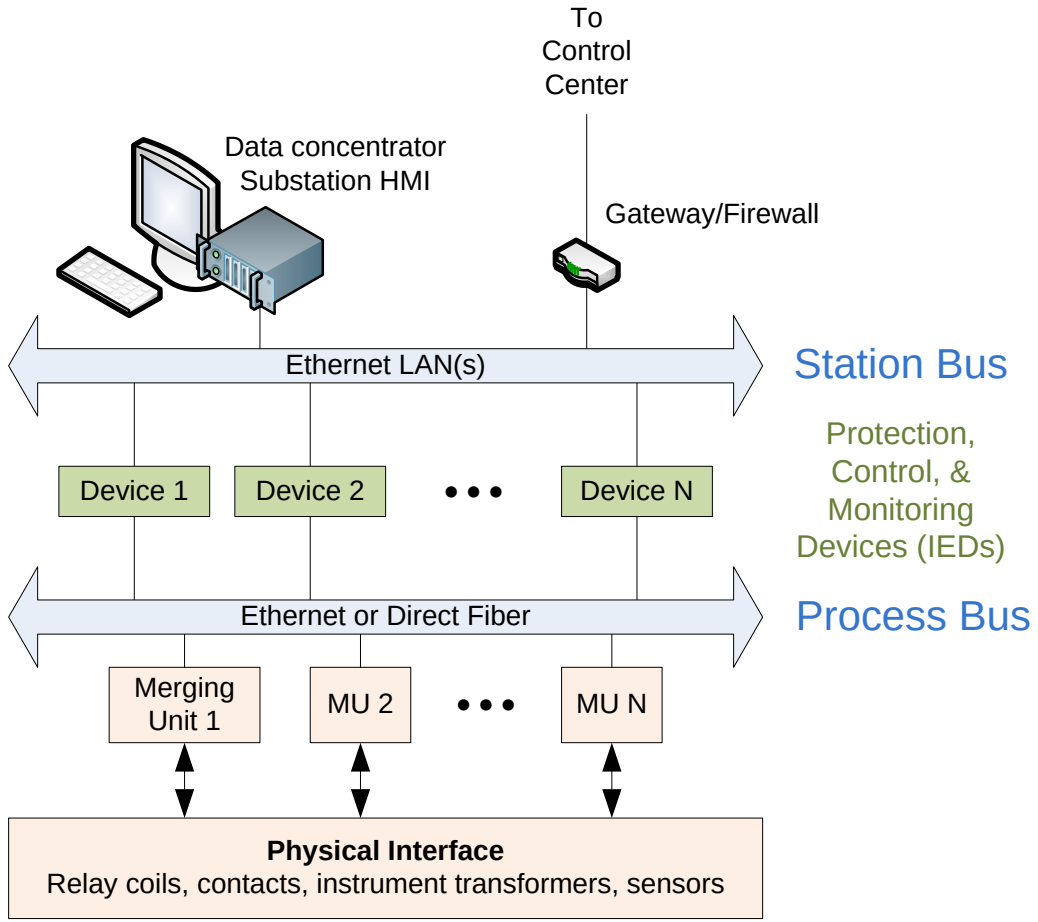
Architecture

- Station Bus
  - Relays, meters, data concentrators, RTUs, etc.
- Process Bus
  - Replace wiring with digitized, high speed data



Architecture

- SCADA
- Instantaneous messaging
  - “Digital wiring”
- Configuration
  - Reduce vendor-specifics
- Other network services
  - Configuration
  - Security
  - File transfer
- Substation “hardening”



Multiple “protocols within the standard”

- Uses MMS (Manufacturing Message Specification) for communication services
- Defines many data classes for scores of applications
- Uses Ethernet extensively and exclusively (ISO and IEEE standards)
- Merging Units per IEC 61869-9
- Configuration using XML

Object-oriented data model

DNP3 Points List (example: analog points)

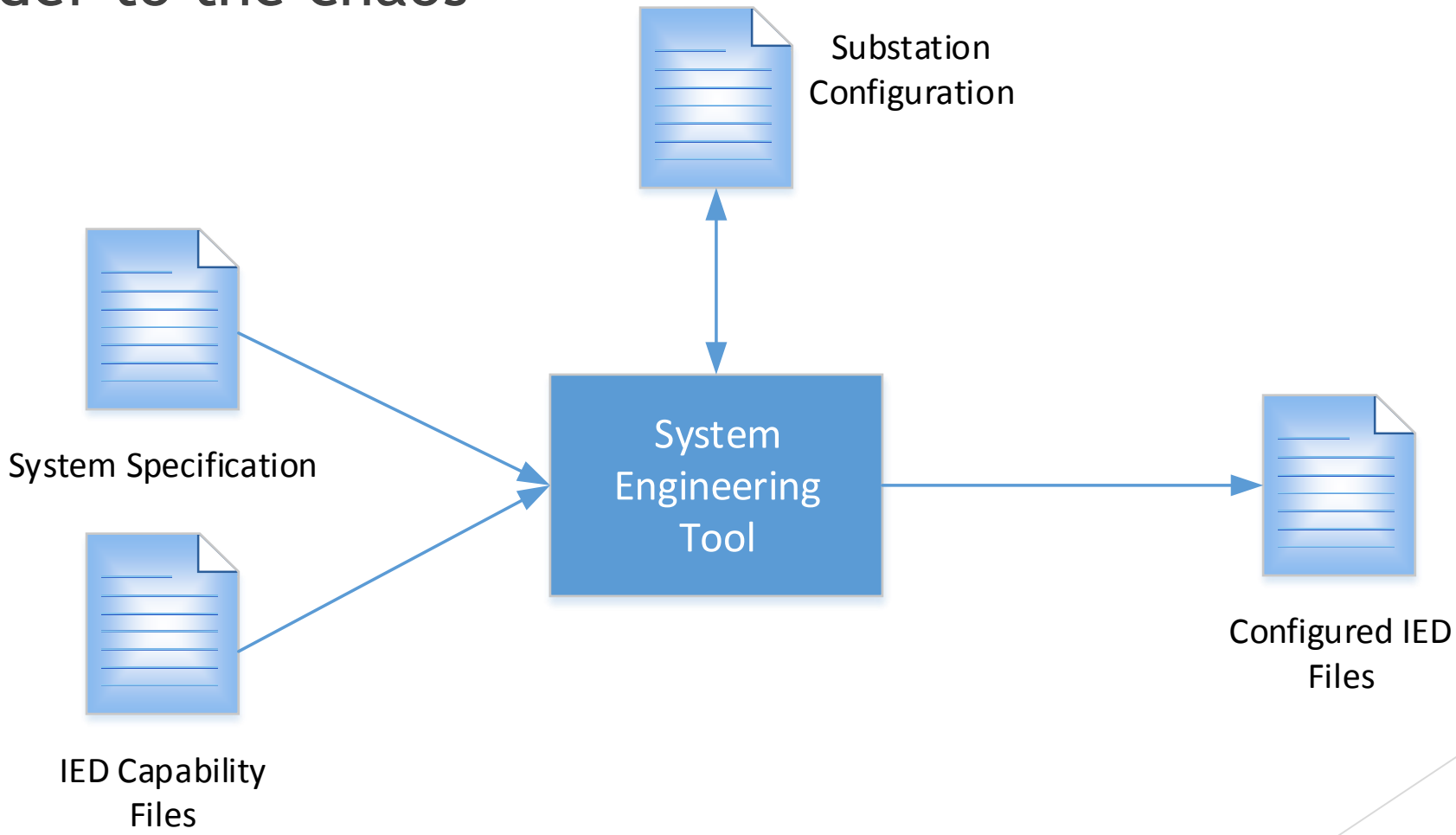
Description	Index	Hex Index	Default Event Class	Division Scale Factor	Units	Deadband
A Phase Primary Current Magnitude	00	00	2	10	Amps	100
B Phase Primary Current Magnitude	01	01	2	10	Amps	100
C Phase Primary Current Magnitude	02	02	2	10	Amps	100
3I0 Primary Current Magnitude	03	03	2	10	Amps	100
A Phase Primary Voltage Magnitude	04	04	2	1	Volts	1000
B Phase Primary Voltage Magnitude	05	05	2	1	Volts	1000
C Phase Primary Voltage Magnitude	06	06	2	1	Volts	1000

Objects

Expression	Type	Value
FM_INST_P_WATTS	MV	
instMag	REAL	0
mag	REAL	0
range	RANGE_T	normal
q	quality_t	
validity	VALIDITY_T	good
detailQual	detailQual_t	
source	SOURCE_T	process
test	BOOL	FALSE
operatorBlocked	BOOL	FALSE
t	timeStamp_t	
db	REAL	100
zeroDb	REAL	2

Configuration

Order to the chaos



Conformance Testing (screenshot from wikipedia.org)

Standard Documents [edit]

IEC 61850 consists of the following parts detailed in separate IEC 61850 standard documents

- IEC 61850-1: Introduction and overview
- IEC 61850-2: Glossary
- IEC 61850-3: General requirements
- IEC 61850-4: System and project management - Ed.2
- IEC 61850-5: Communication requirements for functions and device models
- IEC 61850-6: Configuration language for communication in electrical substations related to IEDs - Ed.2
- IEC 61850-7: Basic communication structure for substation and feeder equipment
  - IEC 61850-7-1: Principles and models - Ed.2
  - IEC 61850-7-2: Abstract communication service interface (ACSI) - Ed.2
  - IEC 61850-7-3: Common Data Classes - Ed.2
  - IEC 61850-7-4: Compatible logical node classes and data classes - Ed.2
  - IEC 61850-7-10: Communication networks and systems in power utility automation - Requirements for web-based and structured access to the IEC 61850 information models [Approved new work]
- IEC 61850-8: Specific communication service mapping (SCSM)
  - IEC 61850-8-1: Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2) - Ed.2
- IEC 61850-9: Specific communication service mapping (SCSM)
  - IEC 61850-9-1: Sampled values over serial unidirectional multidrop point to point link
  - IEC 61850-9-2: Sampled values over ISO/IEC 8802-3 - Ed.2
- IEC 61850-10-: Conformance testing

- How can all vendors possibly read all of these standards the same?
- Requires a test system to simulate the “environment” of the device
- Requires the vendor to provide info on “how we did it”
- Fly in the ointment: Does not necessarily ensure “interoperability” between devices (esp. between different manufacturers)
- Definitely does not ensure “interchangability”

Environmental Requirement
IEC61850-3

- Temperature range
  - Operating @ -40ºC to 85ºC (highest class: Cx)
- EMC (Electromagnetic Compatibility)
  - IEC 61000-4-X and 60255-5 covering, for example:
    - Electrostatic immunity
    - RF and magnetic fields
    - Fast Transients
    - Surges and other voltage anomolies
- Anti-shock and anti-vibration
  - 50G AS
  - 5-500 MHz AV

Related Standards (screenshot from wikipedia.org)

- IEC 61850-7-410 — **Hydroelectric Power Plants** - Communication for monitoring and control.
- IEC 61850-7-420 — Communications systems for **Distributed Energy Resources** (DER) - Logical nodes
- IEC 61850-7-500 — Use of logical nodes to model functions of a substation Automation system. [Approved New Work]
- IEC 61850-7-510 — Use of logical nodes to model functions of a Hydro Power Plant. [Approved New Work]
- IEC 61850-90-1 — Use of IEC 61850 for the **communication between substations** [Published]
- IEC 61850-90-2 — Use of IEC 61850 for the communication between control centres and substations [Approved New Work]
- IEC 61850-90-3 — Using IEC 61850 for Condition Monitoring [Approved New Work]
- IEC 61850-90-4 — IEC 61850 - Network Engineering Guidelines [Approved New Work]
- IEC 61850-90-5 — Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118 [Approved New Work]
- IEC 61850-90-6 — Use of IEC 61850 for **Distribution Feeder Automation System** [Approved New Work]
- IEC 61850-90-7 — Object Models for Photovoltaic,Storage and other DER inverters [Approved New Work]
- IEC 61850-90-8 — Object Models for Electrical Transportation (E-Mobility [Approved New Work])
- IEC 61850-90-9 — Object Models for Batteries [Approved New Work]
- IEC 61850-90-10 — Object Models for Scheduling [Approved New Work]
- IEC 61850-80-1 — Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104 [Published]
- IEC 61400-25 — Application of the IEC 61850 methodology for **Wind turbines**
  - More Wind turbine standards…
- IEC 62271-3 — Communications for monitoring and control of high-voltage switchgear (published)

How is data moved from point to point?

MMS (Manufacturing Message Specification)
Station Bus

- Originated in the 1980s – standardized by ISO/IEC
- Foundation for IEC 61850 process data and supervisory control
- Provides:
  - Vendor independence
  - Network services (client/server, events, file transfer, etc.)
  - Standard data definitions, structure, and encoding rules
  - Security mechanisms
- A general standard designed to be used for specific applications (like 61850)

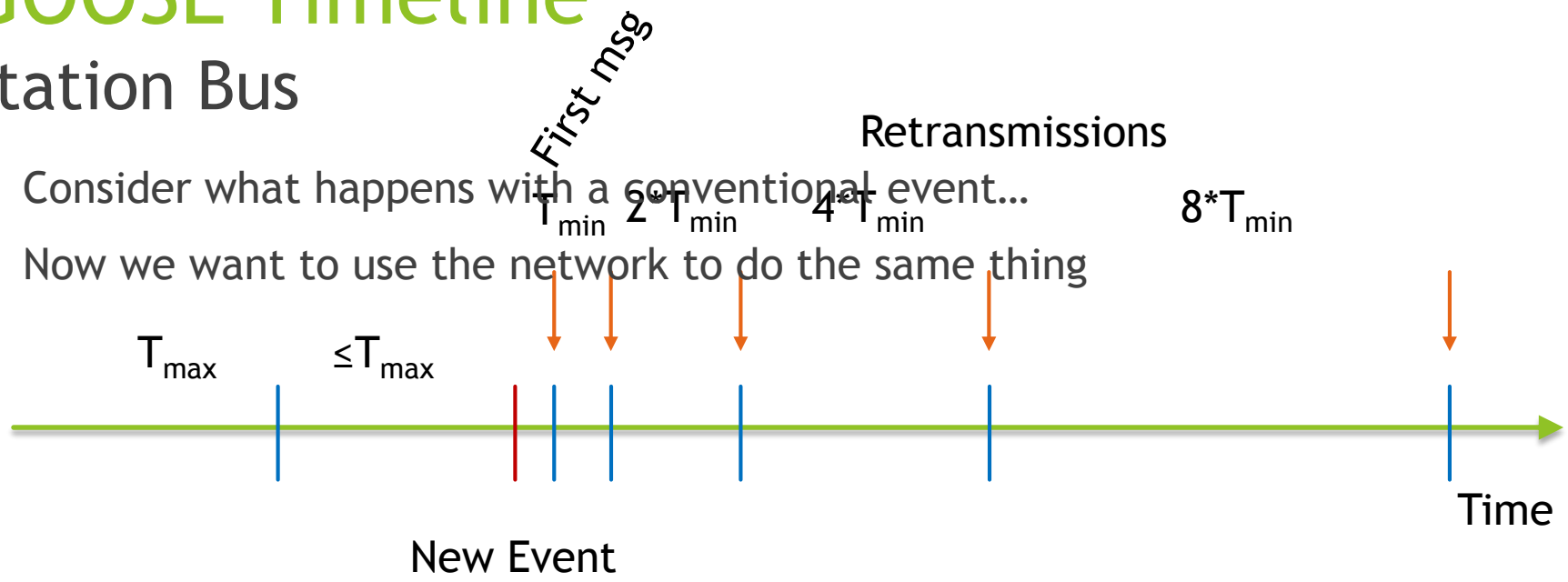
GOOSE (Generic Object Oriented Substation Events)
Station Bus

- Status or analog values (measured values) transmitted on the network
  - Grouped into “data sets”
- Directly embedded in Ethernet packets
  - Multicast or broadcast addresses
- Uses a “publisher/subscriber” paradigm
- Takes advantage of VLANs (virtual LANs) to limit broadcast domain
- Ultra-fast transmit and retransmission for reliable transfer of the message

GOOSE Timeline

Station Bus

- Consider what happens with a conventional event…
- Now we want to use the network to do the same thing



- Faster than a wired connection
  - Traditional: Includes time for output relay (8-10ms), input filtering (5-10ms), I/O signal processing(1-50ms)
  - GOOSE: Processor to processor thru a communication stack and network switch

What does the data look like?

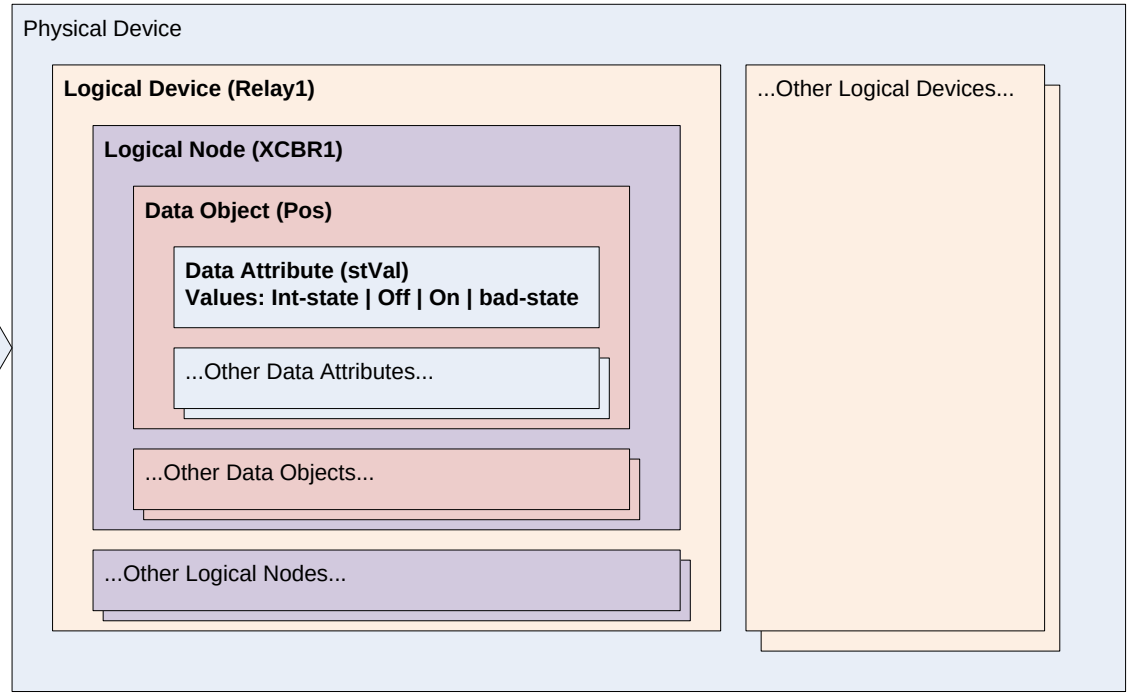
Objects and nodes and attributes, oh my!

IEC 61850

Data model

- Point numbers/names replaced with standard naming convention
- Very structured hierarchy, i.e. classes, std. types
- Data mapped to network services – MMS and Ethernet

LAN Connections



Relay1/XCBR1.Pos.stVal

- Terminology
  - Physical Device = the actual computer/box that has a network address
  - Logical Device = collections of logical nodes in one IED
  - Logical Node = defined functions, e.g. XCBR; defined in the standard
  - Data Object = encapsulate properties of the logical nodes
  - Data Attribute = structured and defined data

Another Data Model Example

- Logical Node = MMXU1
  - Polyphase measurement unit
- Data Object = Amps
  - Phase current
- Sub-Data Object = phsC
  - Phase C
- Attribute = cVal
  - Complex value
- cVal is a vector_t type
  - ***mag***, ***ang*** data values

- MMXU1
  - Volts
  - Amps
    - phsA
    - phsB
    - phsC
      - cVal
        - ***mag***
        - ***ang***

`Relay1/MMXU1.Amps.phsC.cVal.mag`

Standardized logical nodes (as of 2012)

LN Group	First Letter Designator	Number of LNs Defined
System	L	9
Automatic Control	A	5
Control	C	6
Decentralized Energy Resources	D	32
Functional Blocks	F	19
Generic	G	4
Hydro Power	H	19
Interfacing and Archiving	I	7
Mechanical and non-electric primary equipment	K	10
Metering and measurement	M	22
Protection functions	P	32
Power quality events	Q	6
Protection related functions	R	12
Supervision and monitoring	S	15
Instrument transformers and sensors	T	37
Wind turbines	W	16
Switchgear	X	3
Power transformers	Y	4
Further power system equipment	Z	25

* From list compiled by Karlheinz Schwarz, SCC

How configuration works

Problem to be solved

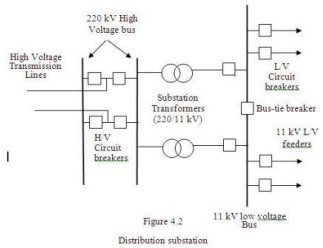
Configuration

- Each equipment manufacturer has a unique program for their device
- Most equipment manufacturers have multiple programs, i.e. one for each “family” of devices
- Each device is more or less standalone
  - No electronic means to tie them together
- Each configuration tool uses a proprietary means of data transport and structure
- Result:

  We have to know lots of tools and lots of tool “features”

Substation Configuration Language
IEC 61850-6

- Based on XML (eXtensible Markup Language)
  - Encoding rules, text, computer readable, tagged data, schemas
- Allows for describing everything in the substation
  - single line diagrams
  - functions in devices
  - much more…
- 61850 defines mandatory and optional parts
- 61850 defines default parameters



.SSD

System Specification

.ICD

IED Capability Files

.SCD

Substation Configuration

System Engineering Tool

Independent and manufacturer software

Project/system documentation

.CID

Configured IED Files

Manufacturer software

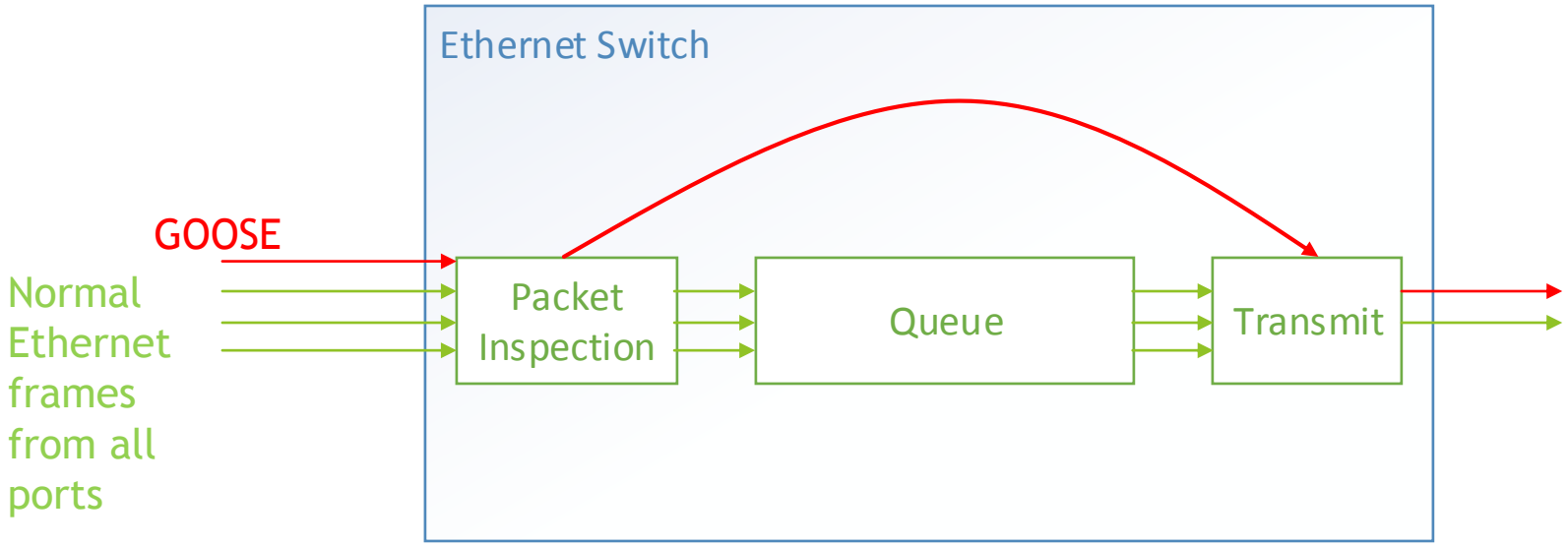
Network reliability

…and why it is REALLY important for 61850

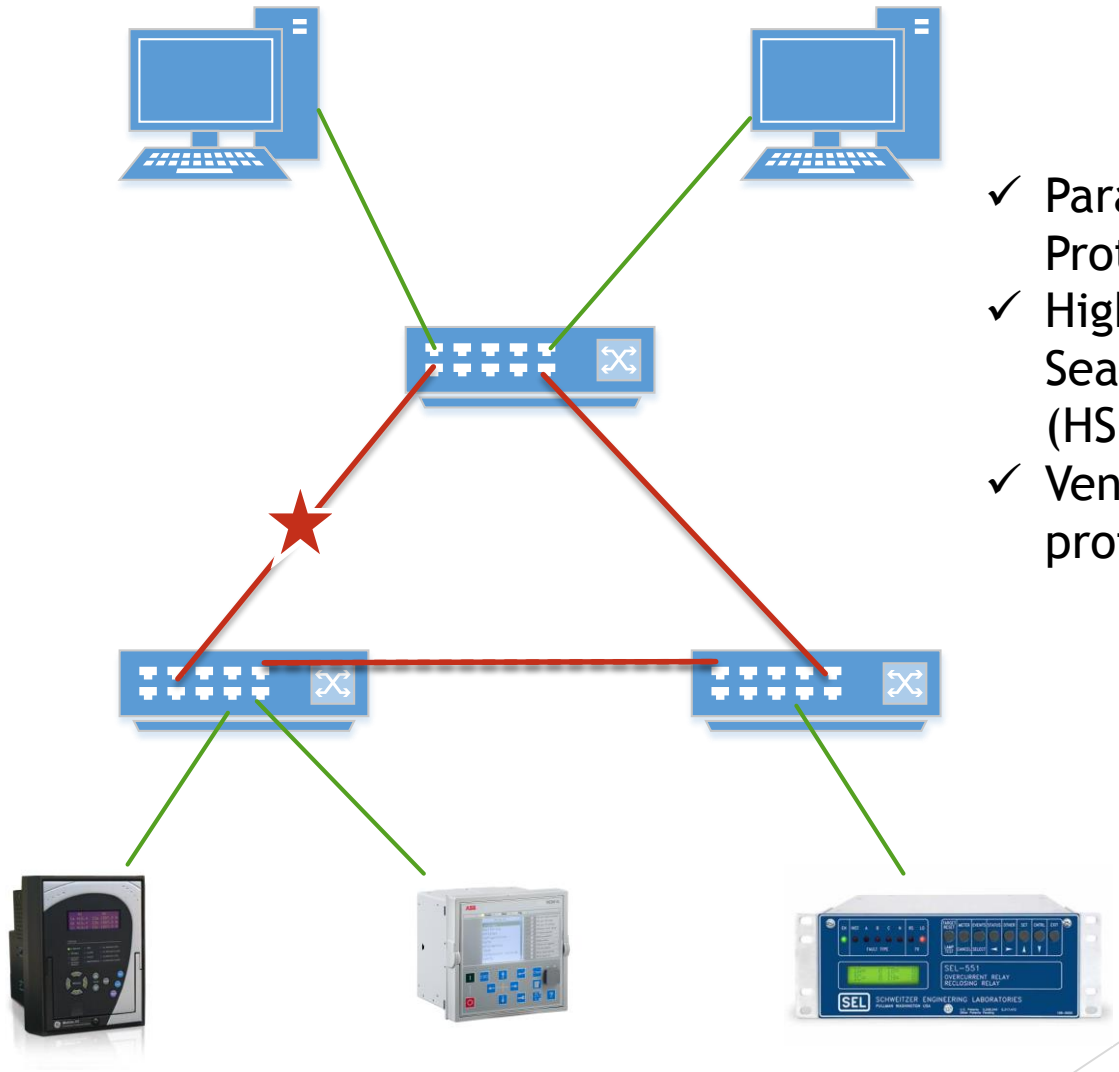
Important Features of Managed Switches

- Backbone of the substation network
  - All data goes through a switch
  - Route Ethernet packets to one or multiple devices
- Buffer packets to/from each port
  - Asynchronous operation = no collisions
  - Mechanism = Store and forward queues
- Virtual local area network (VLAN)
  - A subset of ports – no routing between VLANs at the switch level
  - Contains broadcast and high-bandwidth apps to this subset
- Redundancy
  - Detect and re-route when a link is broken
- Priority routing
  - Higher priority, i.e. GOOSE, transmitted before normal traffic

Prioritizing packets

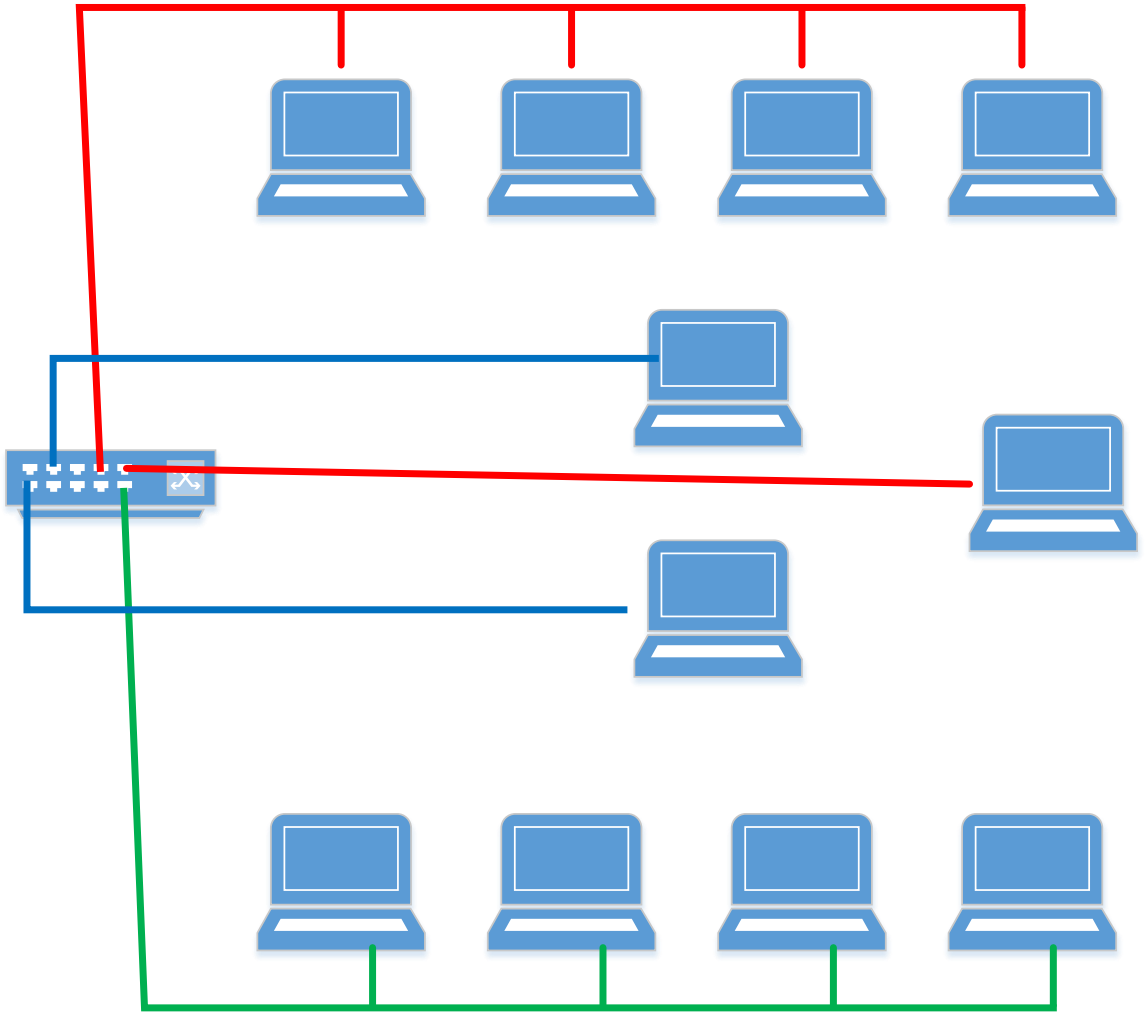


Redundancy



- ✓ Parallel Redundancy Protocol (PRP)
- ✓ High-availability Seamless Redundancy (HSR)
- ✓ Vendor propriety protocol

Virtual LANs



- ✓ Limit broadcast domains
- ✓ Security
- ✓ Simplify network design (via multiple switches)

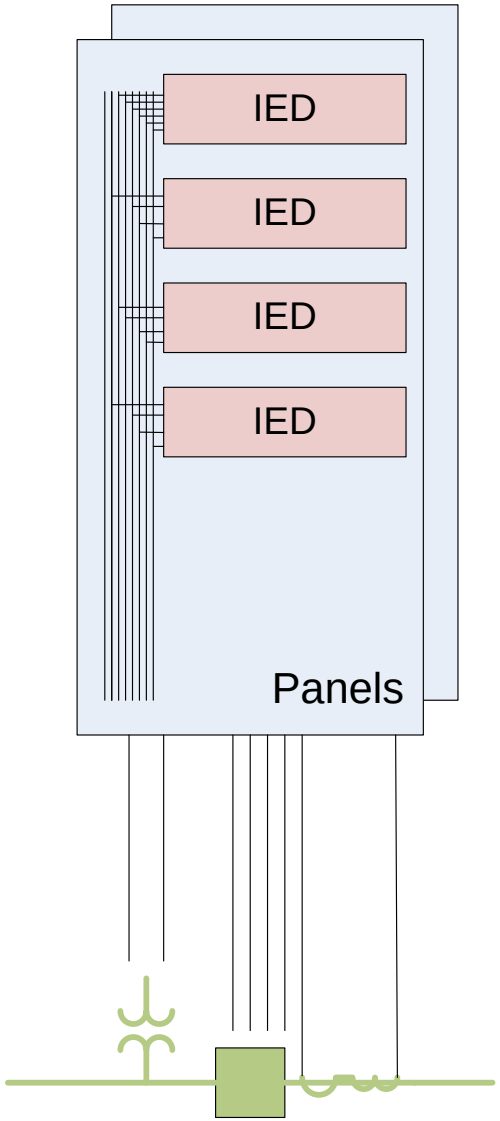
Process Bus

…the final frontier

Purpose of the Process Bus

- Process Bus
  - Purpose: Replace many wires/cables from primary to secondary equipment (relays & other IEDs) with fewer network connections (typically fiber optic)
  - Added flexibility that comes with a digital solution
- Two methods
  - IEC 61850-9-2 LE (ABB, Alston, Siemens)
  - HardFiber™ (GE)
- Moves the Analog-to-Digital function from inside the relays to the "process"

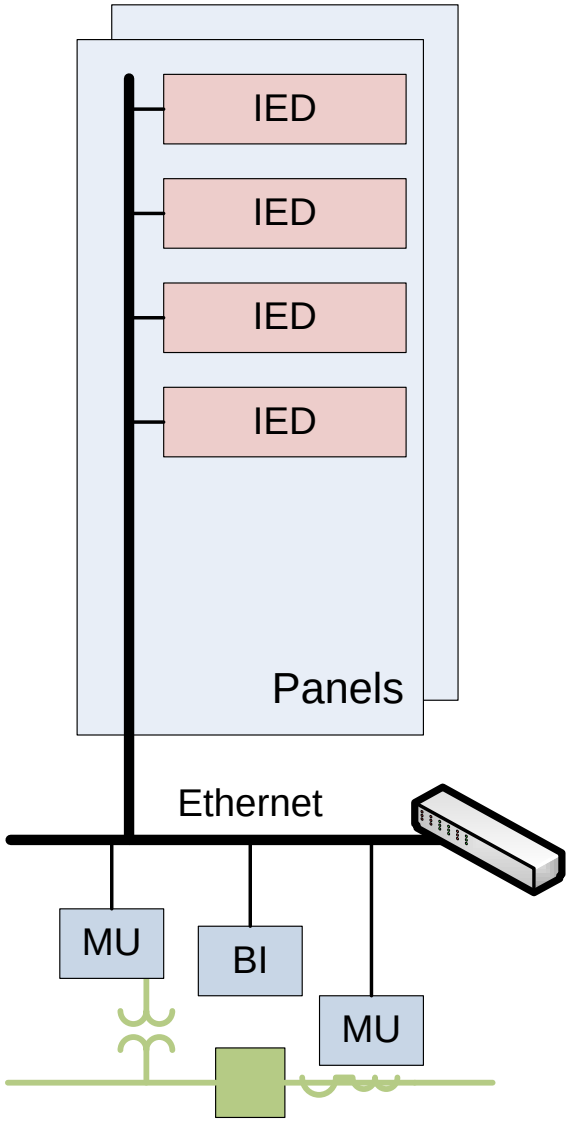
Conventional



Conventional

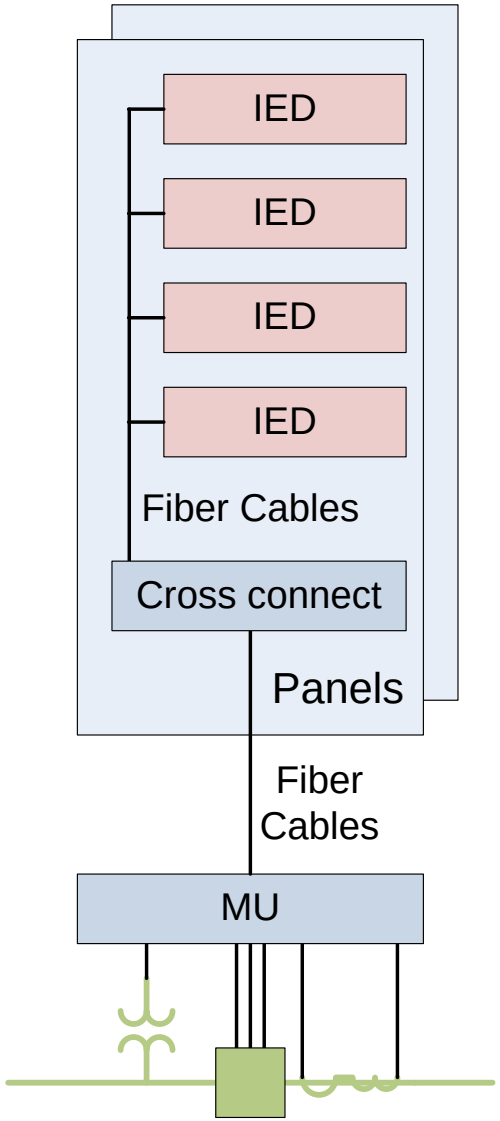
61850-9-2

- MU = Merging Unit
- BI = Binary I/O



61850-9-2 LE

HardFiber™



HardFiber

Summary

The Good and the Bad

- Good
  - Simplified design, i.e. fewer wires
  - Faster and more flexible protection schemes
  - Standardized configuration
- Bad
  - Interoperability (as well as interchangeability) is still a work in progress (and may always be)
  - Cost
  - Maintainability

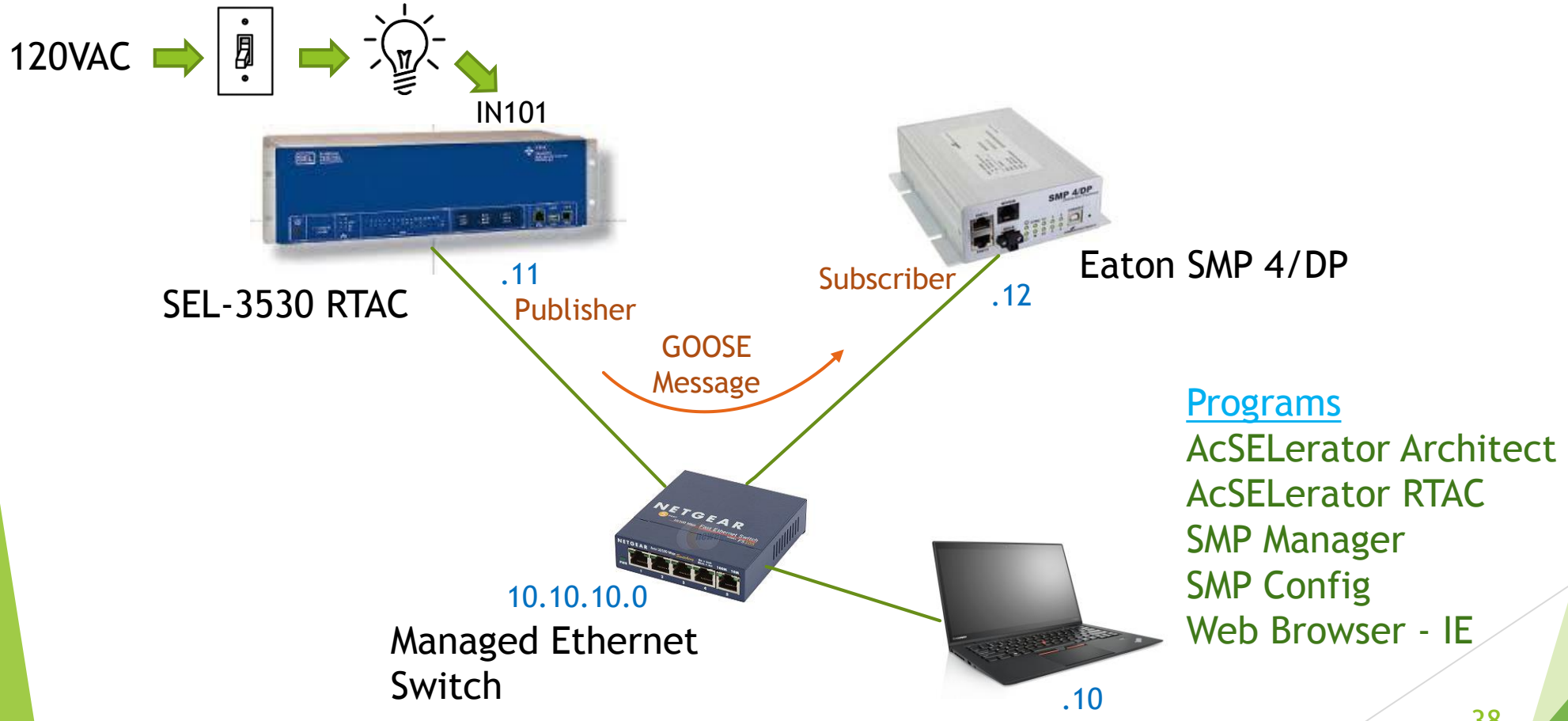
Summary

Where to Start?

- Substation Ethernet - opportunity to access data more efficiently and provides a foundation for the future
- Consider: Greenfield? Brownfield? Turnkey vs. self-implement?
- Look into GOOSE messaging – fairly simple and interoperable
  - Can add some flexibility and remove “out of control” wiring
- Understand the knowledge requirements
  - Like any new technology – requires training, testing, people, etc.
- Press vendors for interoperable adherence to the standards – and have them prove it

Demo of GOOSE messaging

Leveraging the high speed network



[Programs]
AcSELerator Architect
AcSELerator RTAC
SMP Manager
SMP Config
Web Browser - IE

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Q&A

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