IEC 61850 users group

IEC 61850 Tutorial

November 15, 2011

UCA International Users Group

UCAIug Summit Meeting
Austin, TX

IEC 61850 Technical Overview

And Summary of Other Related IEC Standards

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SISCO

Systems Integration Specialists Company, Inc.

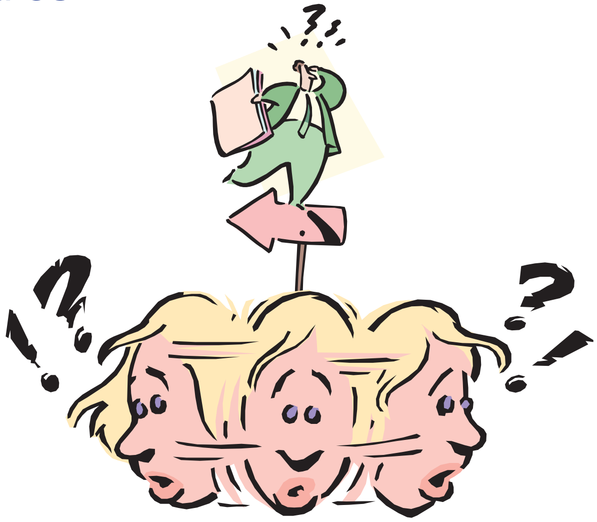
Acronyms

Acronyms are unavoidable when discussing communications and integration technology.

It was our objective to define all acronyms before using them.

If you are not certain, please ask a question.

Ground Rules



Have a Question?
Ask a Question As Needed!

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IEC TC 57 Standards

The Goal:

Interoperability and Integration

The ability of a system to exchange information with other systems and interact with each other in order to perform a useful function for the user.

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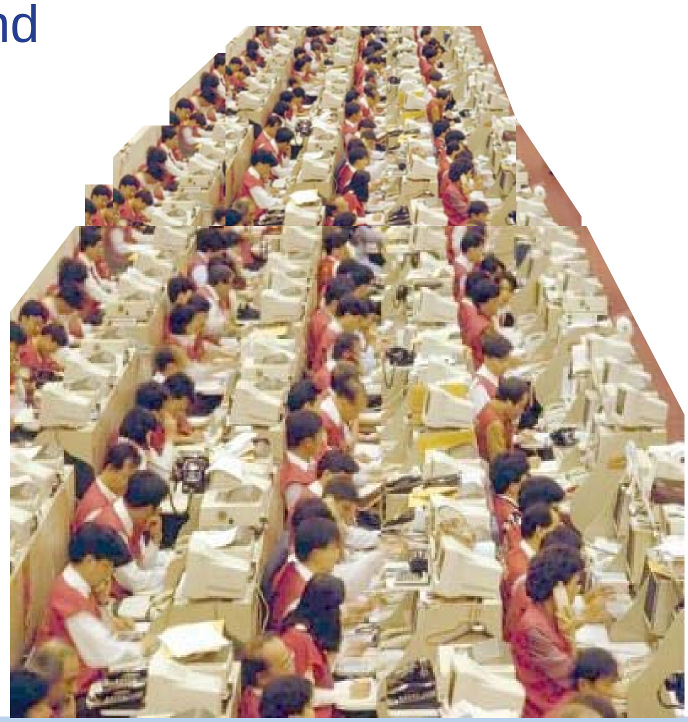
Interoperability and Integration

- Easy to Achieve:



Nearly anything is possible with enough money and development effort

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A Better Way

- Interoperability and Integration without having to create, support, maintain, improve, and fix it all yourself:
  - Where applications and devices are inherently capable of interoperating with other systems and performing integrated application functions in a cooperative and distributed manner.
- This is only possible with Standards
- This is the goal of the IEC TC57 standards

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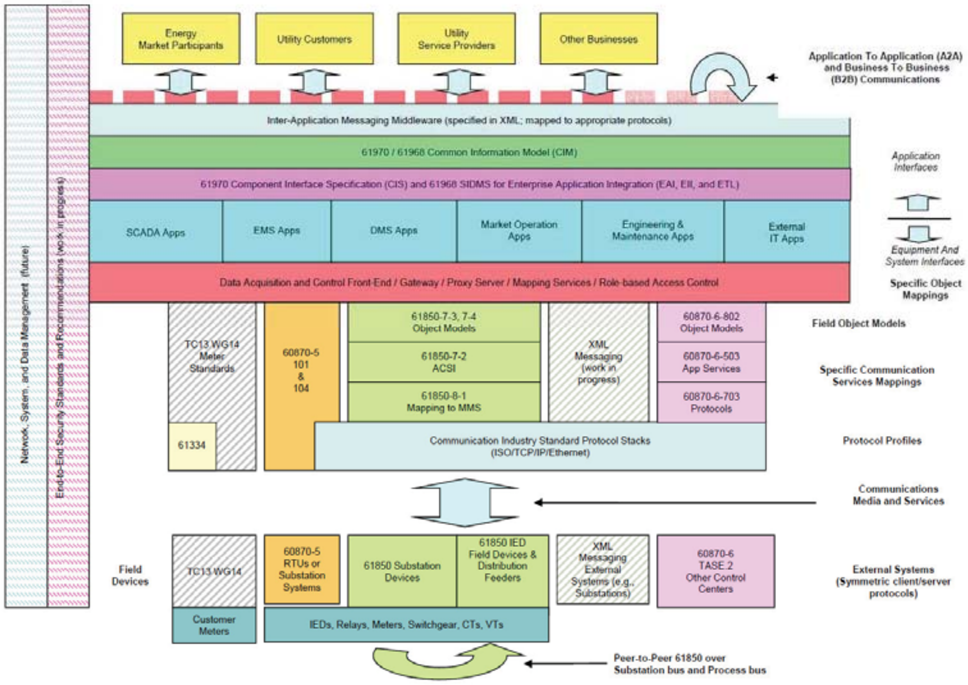
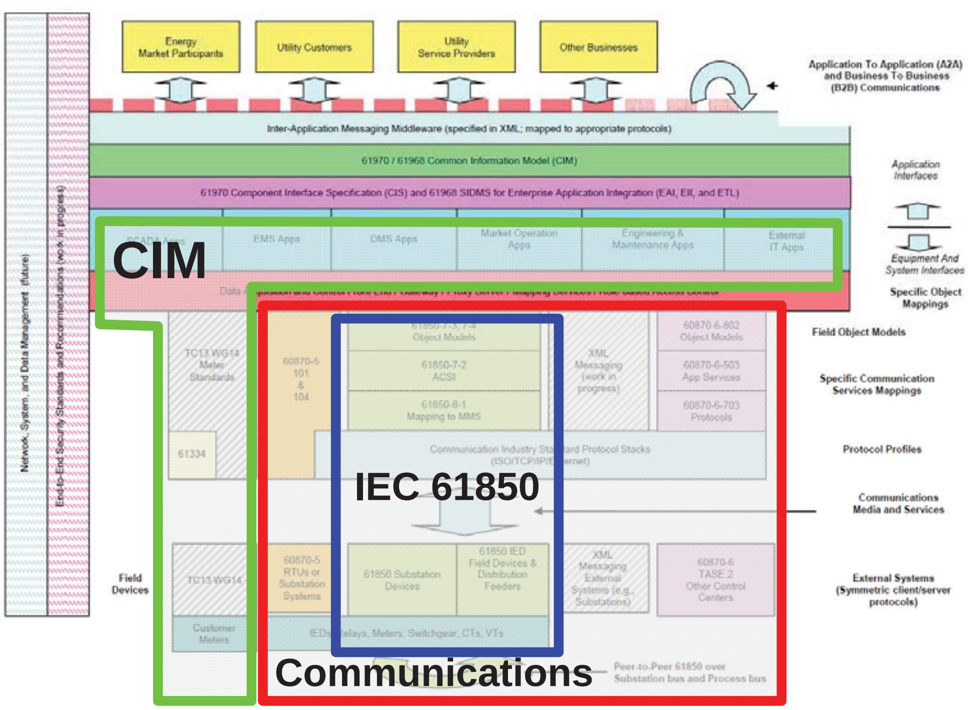
Key IEC TC57 Working Groups

- WG 10 - Power system IED communication and associated data models
  - IEC 61850 – **Communications for power system automation**
    - IEC TC88 – IEC 61400-25 series for IEC 61850 interfaces for wind power
- WG 13 - Energy management system application program interface (EMS - API)
  - IEC 61970 – Common Information Model (CIM) and Generic Interface Definition (GID)
- WG 14 - System interfaces for distribution management (SIDM)
  - IEC 61968 – CIM for distribution and model driven messaging
- WG 15 - Data and communication security
  - IEC 62351 – Communications Security
- WG 16 - Deregulated energy market communications
  - IEC 62325 – CIM for energy markets
- WG 17 - Communications Systems for Distributed Energy Resources (DER)
  - IEC 61850-7-420 – IEC 61850 for DER applications
- WG 18 - Hydroelectric power plants - Communication for monitoring and control
  - IEC 61850-7-410 – IEC 61850 for Hydropower applications
- WG 19 - Interoperability within TC 57 in the long term
  - TC57 strategy and coordination
  - CIM – IEC 61850 Harmonization
  - ICCP-TASE.2 Update


Energy Market Participants
Utility Customers
Utility Service Providers
Other Businesses
Application To Application (A2A) and Business To Business (B2B) Communications
Inter-Application Messaging Middleware (specified in XML; mapped to appropriate protocols)
61970 / 61968 Common Information Model (CIM)
61970 Component Interface Specification (CIS) and 61968 SIDMS for Enterprise Application Integration (EAI, EII, and ETL)
Application Interfaces
SCADA Apps
EMS Apps
DMS Apps
Market Operation Apps
Engineering & Maintenance Apps
External IT Apps
Equipment And System Interfaces
Data Acquisition and Control Front-End / Gateway / Proxy Server / Mapping Services / Role-based Access Control
Specific Object Mappings
Network, System, and Data Management (future)
End-to-End Security Standards and Recommendations (work in progress)
TC13 WG14 Meter Standards
60870-5 101 & 104
61850-7-3, 7-4 Object Models
61850-7-2 ACSI
61850-8-1 Mapping to MMS
XML Messaging (work in progress)
60870-6-802 Object Models
60870-6-503 App Services
60870-6-703 Protocols
Field Object Models
Specific Communication Services Mappings
61334
Communication Industry Standard Protocol Stacks (ISO/TCP/IP/Ethernet)
Protocol Profiles
Communications Media and Services
Field Devices
TC13 WG14
60870-5 RTUs or Substation Systems
61850 Substation Devices
61850 IED Field Devices & Distribution Feeders
XML Messaging External Systems (e.g., Substations)
60870-6 TASE.2 Other Control Centers
External Systems (Symmetric client/server protocols)
Customer Meters
IEDs, Relays, Meters, Switchgear, CTs, VTs
Peer-to-Peer 61850 over Substation bus and Process bus


CIM
IEC 61850
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Application Interfaces
Equipment And System Interfaces
Specific Object Mappings
Field Object Models
Specific Communication Services Mappings
Protocol Profiles
Communications Media and Services
Field Devices
External Systems (Symmetric client/server protocols)

Strategic Vision for Integration and Interoperability

- Abstract Modeling
  - **Object and Information Models**
  - Abstract Service and Interface Models
  - Self Description and Discovery
  - Technology Independent Design
- Security
  - Applying mainstream standards to TC57 standards
  - Power system specific applications and recommendations

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Review of Key IEC Standards

IEC 61850

Traditional Protocol Standards

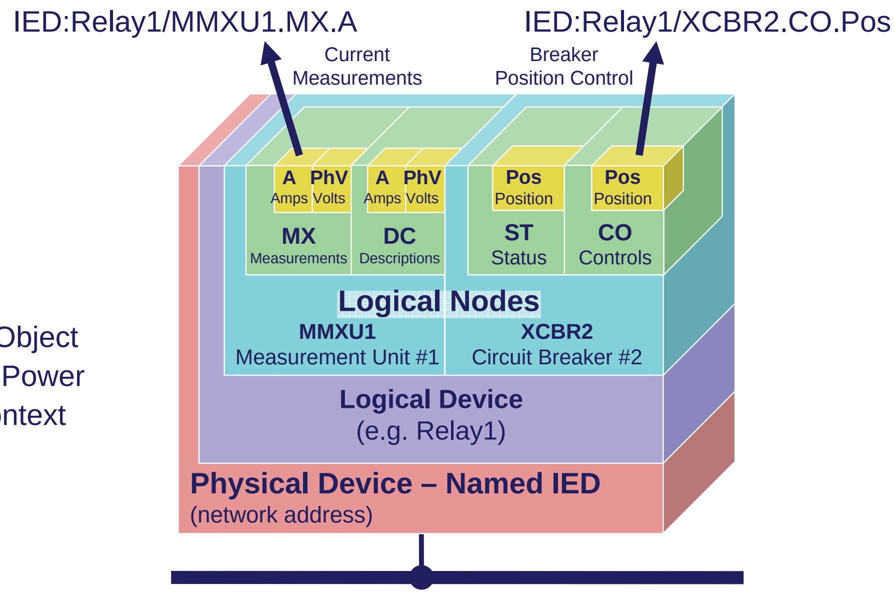
- Specified how you arrange bytes on the wire in order to transfer bytes of data between a device and an application
- **Good News: It worked!** Device communications costs were lowered.
- Bad News: No standard for data representation or how devices should look and behave to network applications.
- **Some Interoperability but not Integration**

IEC61850 is Different

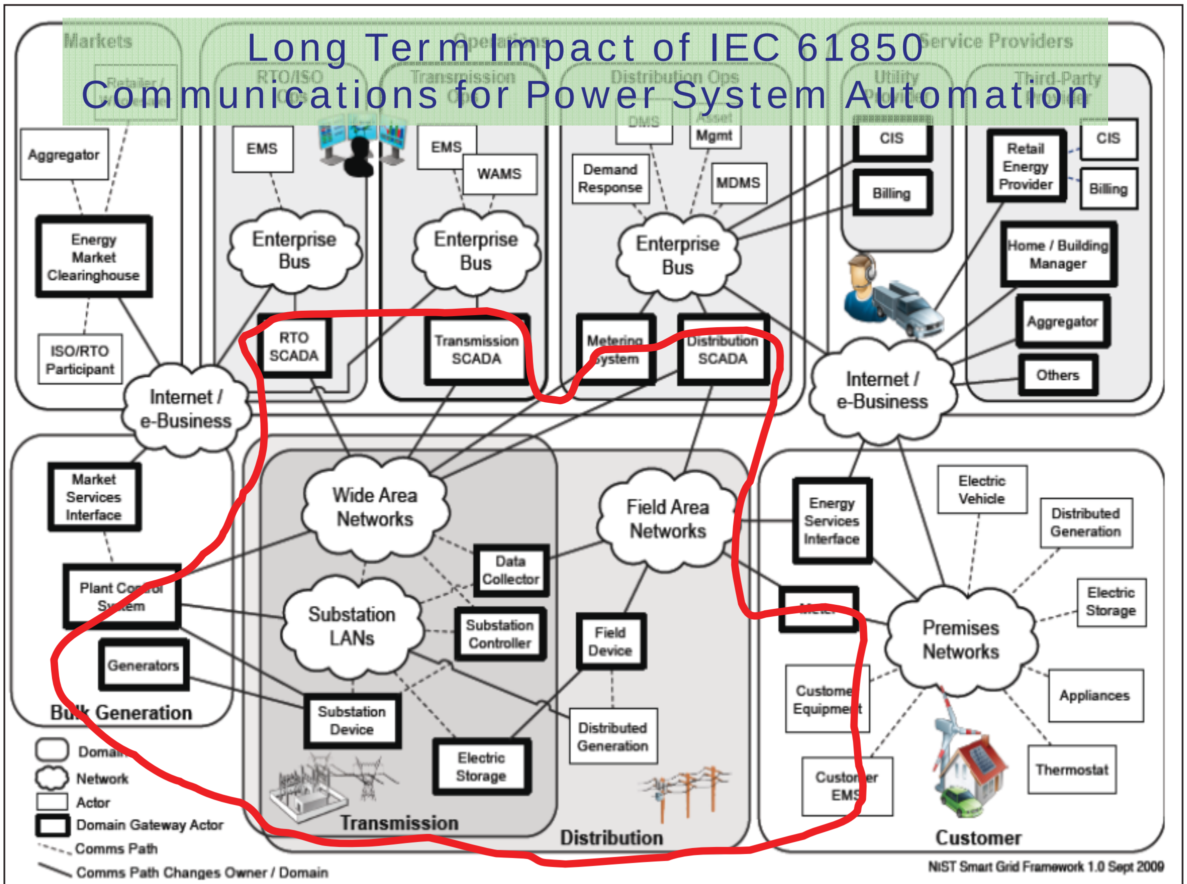
- IEC61850 is an object oriented substation automation standard that defines:
  - Standardized names
  - Standardized meaning of data
  - Standardized abstract services
  - Standardized device behavior models
  - Mapping of these abstract services and models to specific protocols profiles for:
    - Control and Monitoring
    - Protection
    - Transducers
- Companion Standards for:
  - Wind power
  - Hydro power
  - Distributed Energy Resources
  - More coming: synchrophasor, SCADA, wide area protection, etc.

IEC 61850 Object Models

IEC 61850 Object Names Use Power System Context



Long Term Impact of IEC 61850 Communications for Power System Automation



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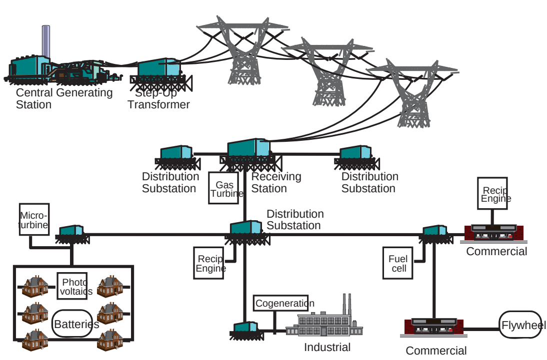
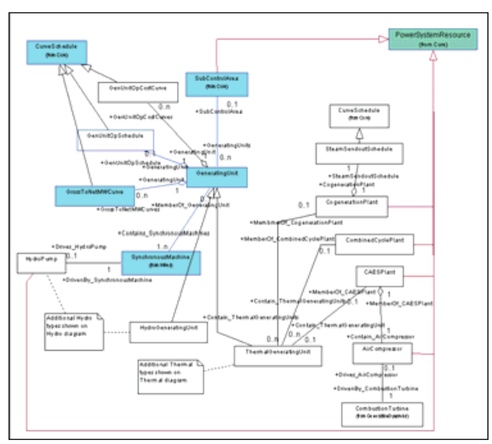
Review of Key IEC Standards

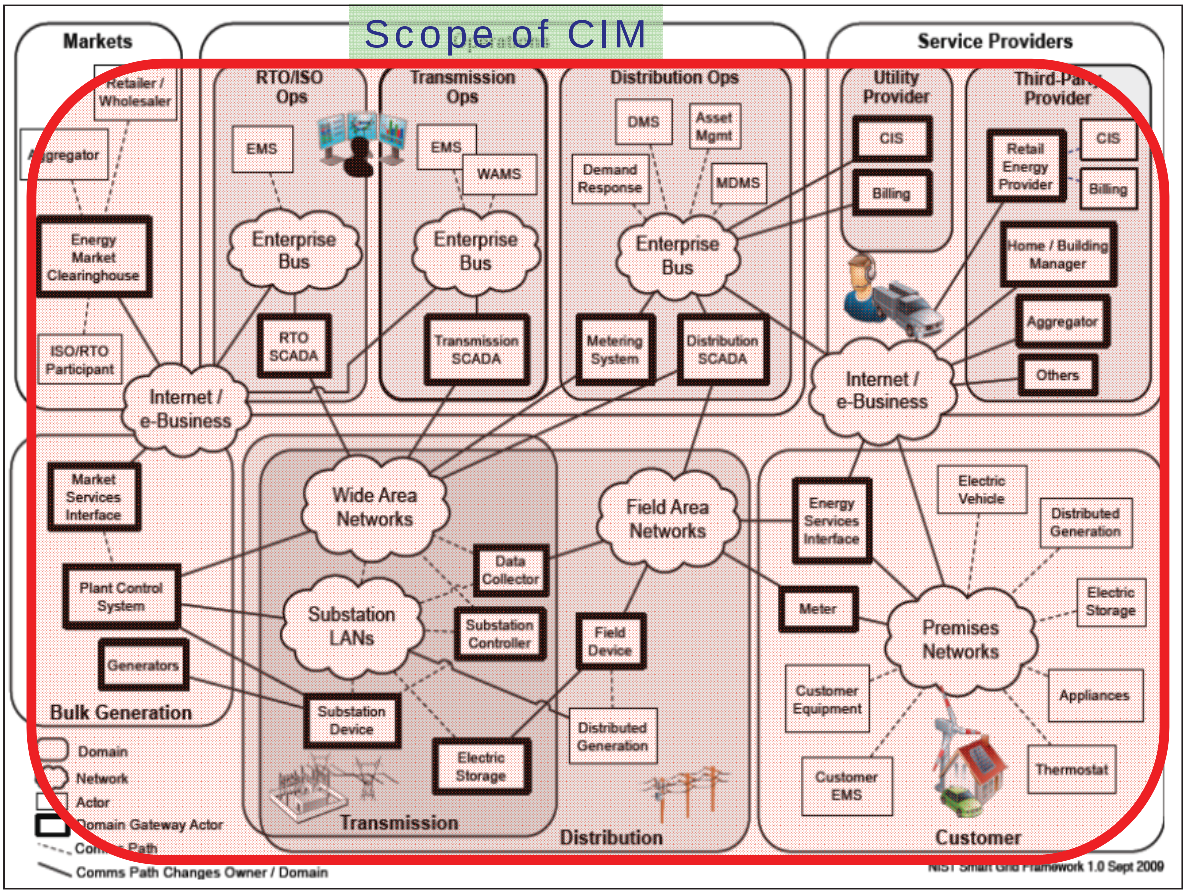
CIM – IEC 61970 and IEC 61968

Common Information Model (CIM) is an object-oriented information model of the power system





UML – Unified Modeling Language



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CIM Packages

IEC 61968 from IEC TC57 WG14

- Assets (metering)
- Documen-tation
- Consumer
- Core2
- ERP
- OAG

Distribution

IEC 61970 from IEC TC57 WG13

- Core
- SCADA
- Load
- Protection
- Outage
- Wires
- Generation
- Measurements
- Domain
- Topology

EMS, Transmission & Planning

IEC 62325 from IEC TC57 WG16

- Financial
- Energy Scheduling
- Reservation
- Market Operations

Markets (Euro & NA)

CIM - What It Is -- And Isn't

- CIM model defines:
  - Object Classes
  - Object Attributes
  - Relationships to other classes
- CIM is not:
  - a database (object or relational)
  - A method to store data, only a method to organize it.
  - Primarily used for interfaces to exchange data
    - Not necessary for all applications to use CIM internally for their own data organization.

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IEC 61970 Standards

- IEC 61970-301 – CIM UML Model
- IEC 61970-401 – Requirements and use cases for info exchange interfaces
- IEC 61970-402 – Common Services
- IEC 61970-403 – Generic Data Access (GDA)
- IEC 61970-404 – High Speed Data Access (HSDA)
- IEC 61970-405 – Generic Eventing and Subscription (GES)
- IEC 61970-407 – Time Series Data Access (TSDA)
- IEC 61970-452 – Power System Model Exchange Profile (Common Power System Model – CPSM)
- IEC 61970-453 – CIM based graphics exchange (one-line diagrams)
- IEC 61970-501 – CIM XML Syntax: UML → XML using RDF schema
- IEC 61970-552-4 – CIM XML Model Exchange for full, partial and incremental

(IEC 61970-402 through 61970-407: Generic Interface Definition (GID))

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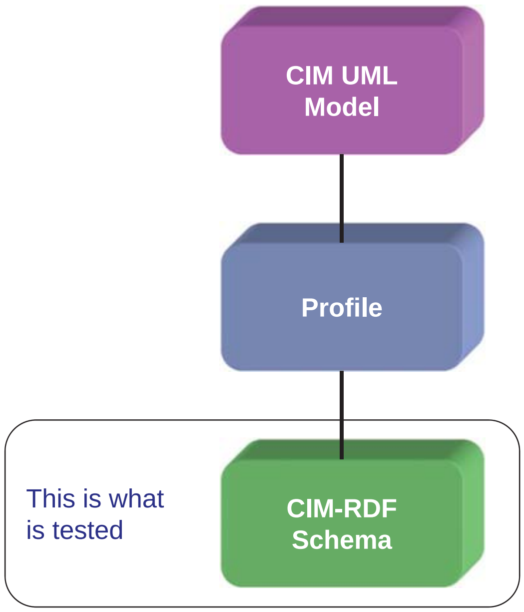
Models, Profiles and Exchange Syntax



- Information model contains all elements needed for the use case
  - From the standard
  - And extensions if needed
- Contextual Layer that restricts the model as needed by the use case
  - Restrictions
  - Identify mandatory and optional elements
  - Cannot add to the model
- Syntax to suit the use case
  - Used to specify file formats (full model, partial model, or incremental model)
  - Message syntax
  - Mapping to technology (e.g. RDF)

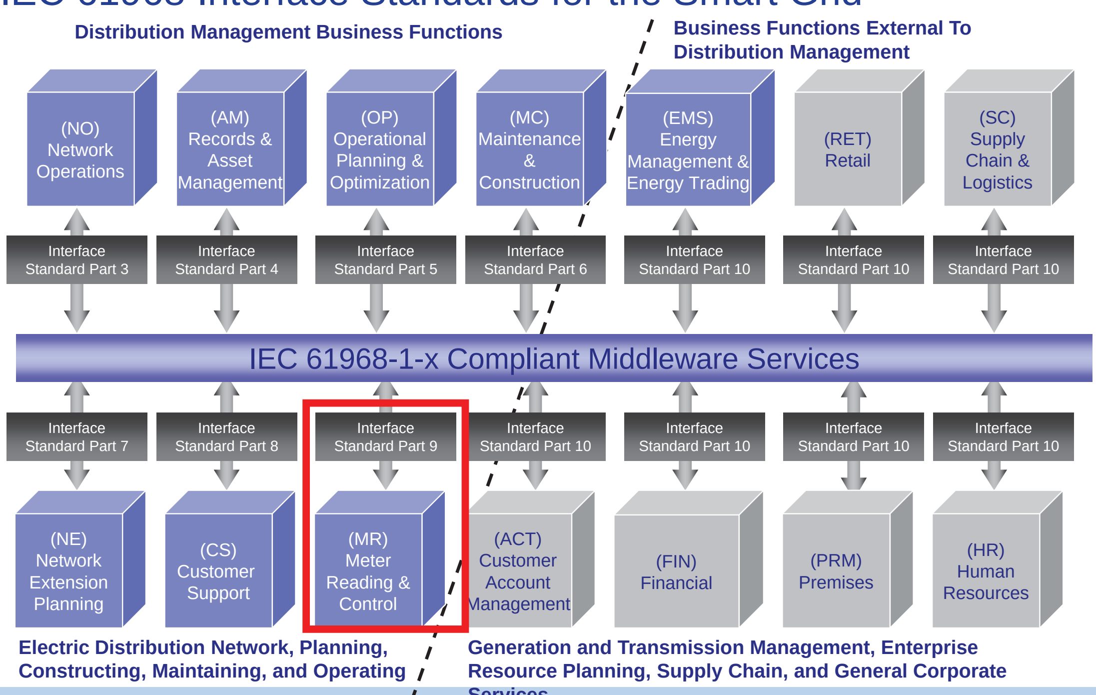
How is CIM Used?

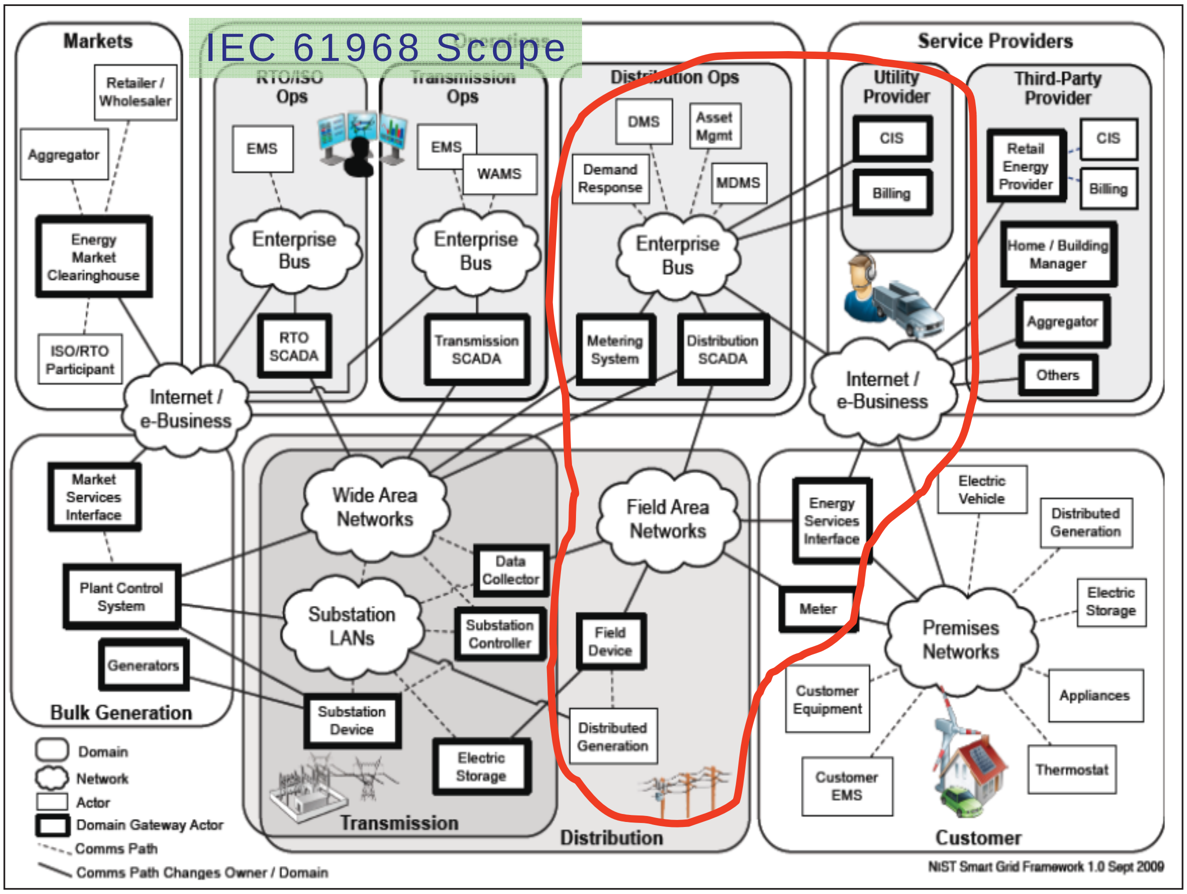
- Power System Model Exchange between neighboring utilities and ISO/RTOs
- Definition of Messages for exchange over an ESB
- Common Data Exchange Model for Application Integration

IEC 61968 Standards

- IEC 61968-1 – Interface Architecture and General Requirements
- IEC 61968-100 – Web Service, JMS, and Enterprise Service Bus (ESB) Implementation Profile
- IEC 61968-11 – Common Information Model for Distribution
- IEC 61968-13 – Common Distribution Power System Model (CDPSM) profile for model exchange
  - Uses IEC 61970-501 and IEC 61970-552-4
  - Analogous to IEC 61970-452
- IEC 61968-14 – Mapping to Multispeak
  - Multispeak is a set of non-CIM messages that have been used in USA
- IEC 61968 Parts 3 through 10 – Interface Standards

IEC 61968 Interface Standards for the Smart Grid





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IEC Communications
Security

IEC 62351

IEC 62351 Communications Security

- Specifications for securing IEC TC57 protocols for:
  - Strong **Application Level Authentication** using digital certificates
  - **Confidentiality via encryption** using transport layer security (TLS)
  - **Prevention of spoofing** via use of digitally signed connection messages
- Supports:
  - IEC 61850 profiles for:
    - TCP/IP (Core ACSI Services: reporting, controls, settings, etc.)
    - GOOSE – protection messaging
    - Sample Values – process bus messaging
  - ICCP – IEC 60870-6 TASE.2 using TCP/IP
  - IEC 60870-5-104 using TCP/IP
    - Also works with DNP3

Open Smart Grid Users Group – UtilitiSec Working Group

- Advanced Security Acceleration Project for the Smart Grid (ASAP-SG)
  - Provide security guidelines for smart grid applications and the strategies and guiding principles used in their creation.
- AMI Security Task Force
  - Focused on AMI security
- Goals:
  - deliver security guidelines before it's too late (e.g., before costly investments have already been made in infrastructure that cannot be updated)
  - supply security guidance that is as broadly applicable as possible, regardless of the size of a utility or the particular technologies used
  - supply actionable guidance for procurement activities in a form that is easily put to use by utility and vendor communities

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IEC 61850 and CIM:

Overview, How They Fit, and Harmonization

CIM versus IEC 61850: What they define

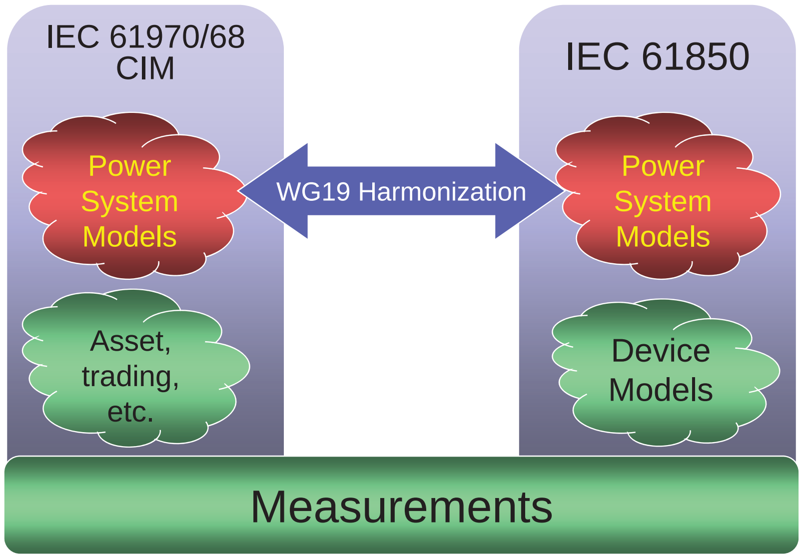
CIM

- Detailed Power System Topology
- Asset Model
- Consumer and load models
- Financial
- Scheduling and transactions
- Market operations
- Work management
- SCADA and Measurements
- GIS – Location
- Business Messaging (WG14)

IEC 61850

- Power System Topology Model
- Device Configuration Description
- Device Models
- Service Models
  - Reporting
  - Controls
  - Protection
- Performance/Requirements
- Object and Data Naming Conventions
- Protocols

CIM Asset-Power System Models & IEC 61850 Device Models



CIM versus IEC 61850: What they define

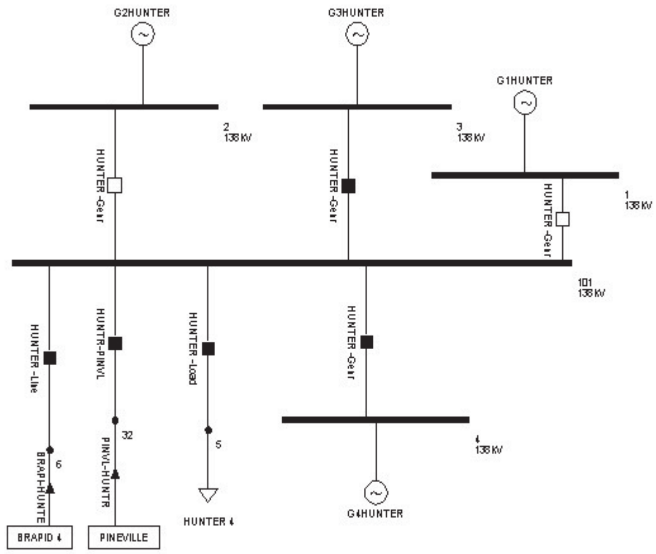
CIM

- Enterprise Power System Connectivity
- Asset Model
- Consumer and load models
- Financial
- Scheduling and transactions
- Market operations
- Work management
- SCADA and Measurements
- GIS – Location
- Business Messaging (WG14)

IEC 61850

- Substation Power System Connectivity
- Device Configuration Description
- Device Models
- Service Models
  - Reporting
  - Controls
  - Protection
- Performance/Requirements
- Object and Data Naming Conventions
- Protocols

CIM Based Modeling Tool



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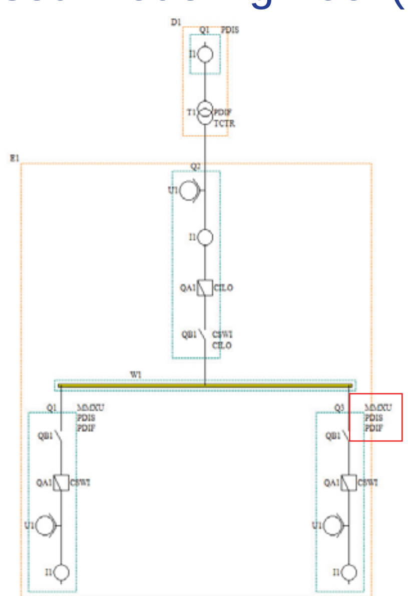
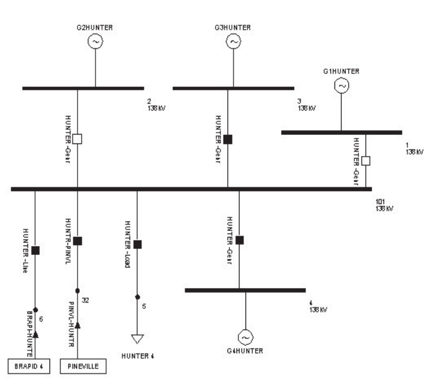
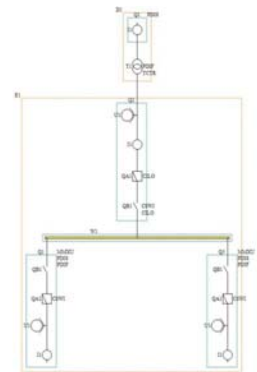
IEC 61850 Based Modeling Tool (SCL)



Logical Node Designators

Two Different Purposes – Two Solutions are OK, BUT





- Detailed system wide description
- Model exchange for high-level systems
- Power flow, state estimation, etc.
- Market operations
- Planning and system design

- Substation design and modeling
- Device configuration management
- Protection and device control
- SCADA, protection, & control data exchange

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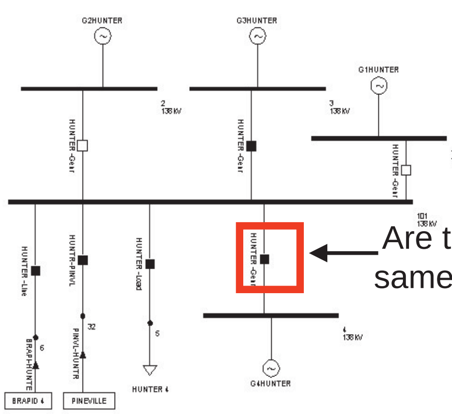
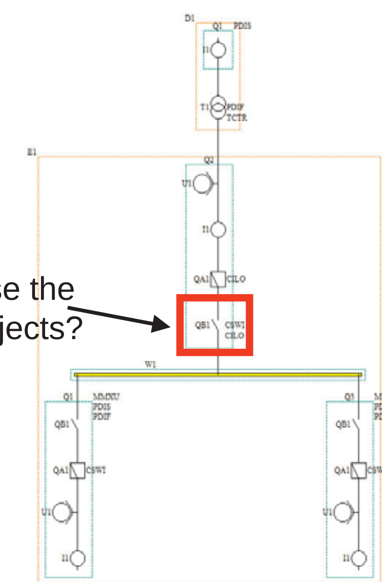
CIM and IEC 61850 Difference in Topology



Are these the same objects?



IEC 61970-301 EMS Diagram

IEC 61850-6-1 SCL Diagram

Why the need for persistent IDs

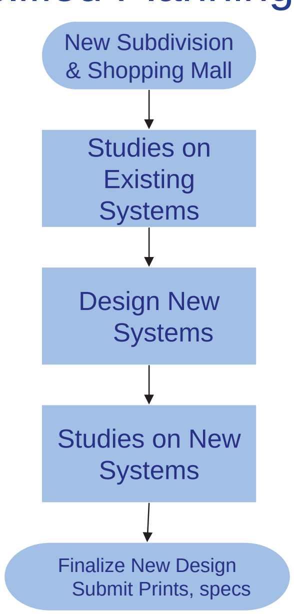
- IEC 61850-6-1 Substation Configuration Language (SCL) files are used to define substation power system toplogy and IED functions and configuration.
- SCL files have internal referential integrity through the use of names.
  - When merged/imported into a unified model, names can be duplicated.
  - It is difficult to pick up changes if the name changes.
- CIM uses GUIDs
- GUIDs are the better solution
  - Common usage
  - Not ambiguous
  - Isolates identification of objects from names

Other Harmonization Issues

- IEC 61850 use of SI Units to be brought into CIM
- Adding topological elements to IEC 61850 and CIM to enable easier path back and forth
  - All IEC 61850 topology is within a substation
- References from CIM objects (like Protection Relay) to IEC 61850 objects formalized
  - Enables unified model of settings, configuration, and SCADA tags
- Unification of control functions that work on power systems resources to IEC 61850 controls and services

Why do CIM and IEC 61850 Need to fit together better?

Simplified Planning Process



- Well defined processes and tools for designing new power system extensions, simulating their impact, defining new contingencies, etc.

Moving Design to Operations

- Since the advent of the CIM the ability to move models from planning to operations (and vice-a-versa) in a multi-vendor environment has improved.
  - To be expected through use of standards.
  - Eventually enable wide exchange of planning models like ENTSO-E and WECC.
- EMS and planning use a set of tools that have been harmonized to enable the flow of information between them.

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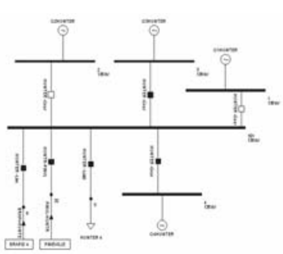
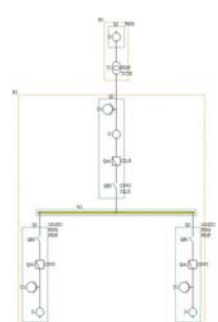
Moving the Design to Substations





- Power system engineers use a completely different set of tools supporting a completely different set of standards to define the substation automation and protection systems.

It's About Productivity

- The effort and knowledge put into the planning and operations models that isn't embodied in the one-line diagrams is lost and has to be transferred manually into the substation design through the engineering process duplicating previous effort.
- If the tools used a common set of standards the flow of information can be automated enabling topology, SCADA, protection, communications, settings, etc. to be preserved and leveraged through the engineering process.

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Questions - Discussion

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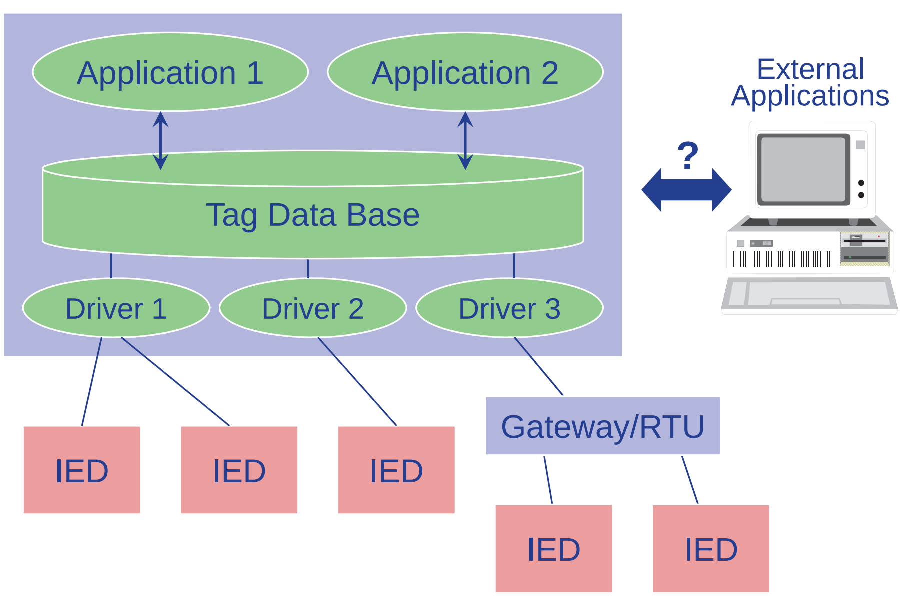
Benefits of IEC 61850

Legacy Substation Network Architecture



Legacy Substation Architecture

- Specialized point to point links to IEDs.
- Applications must deal with numerous:
  - Protocols
  - Data Formats
  - Data Addressing
- Protocols used have limited capabilities and required custom/proprietary extensions.
- Difficult or no access point for other apps.
- Communication path must be reconfigured when new devices or applications are added.

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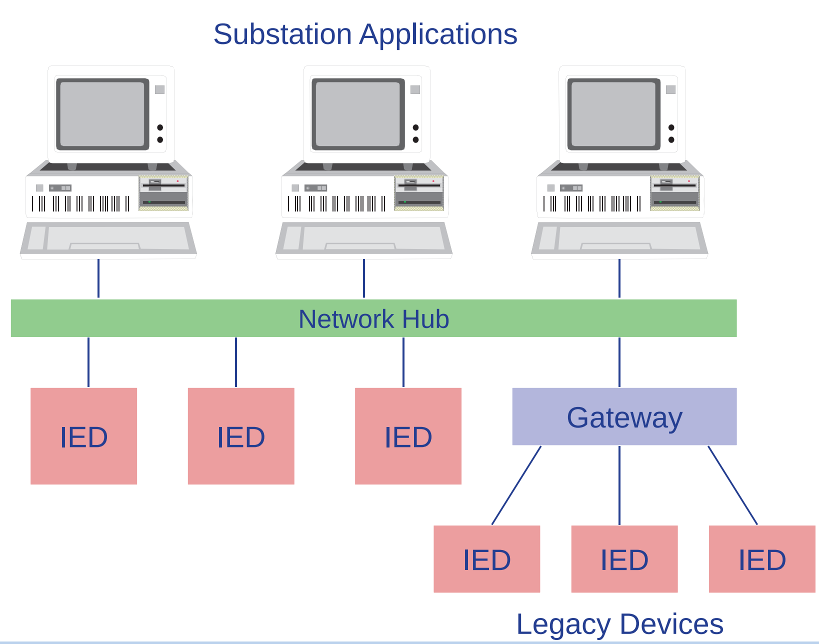
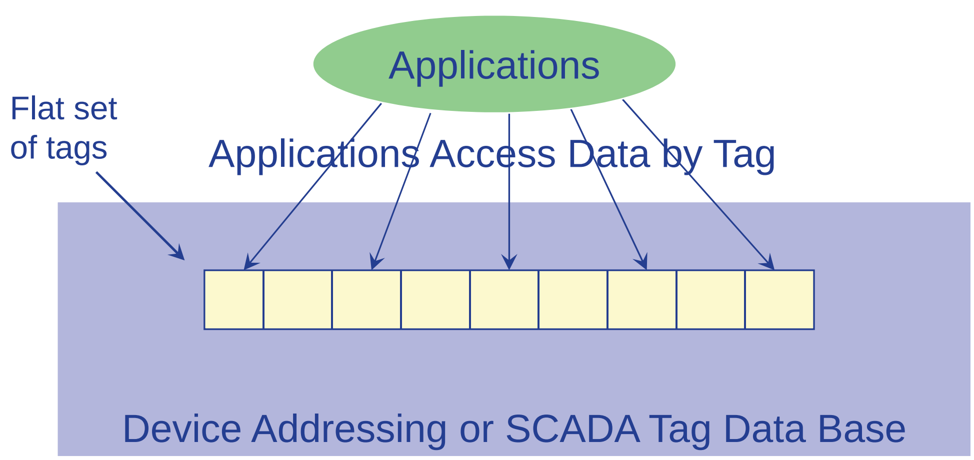
IEC61850 Network Architecture



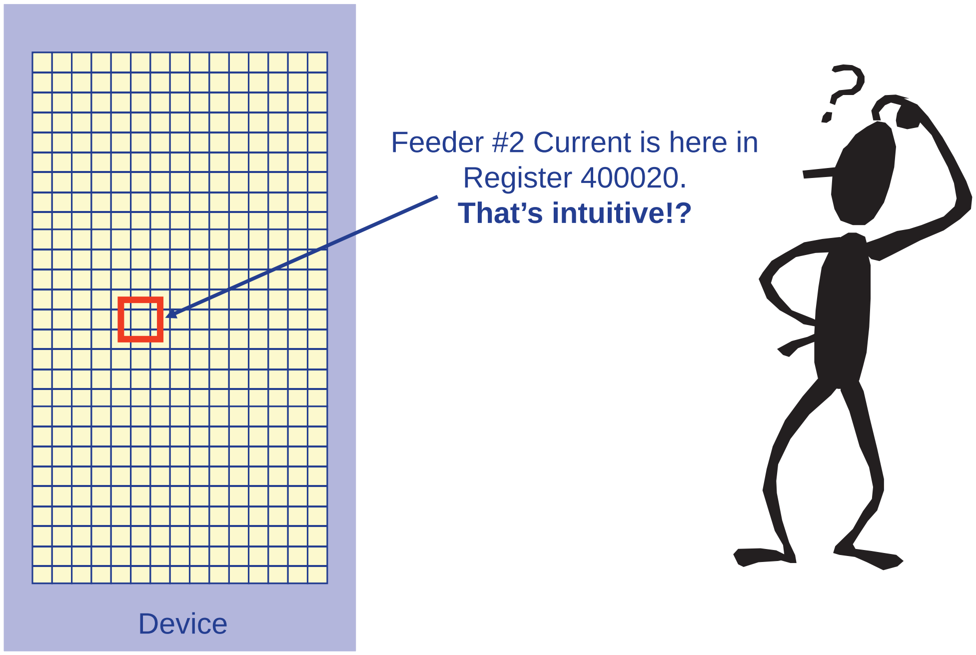
IEC61850 Network Architecture

- Data from IEDs available to all applications via network.
- Communications path unaffected when adding devices or applications.
- Standard networking gear provides high performance, flexibility, & environmental protection.
- Applications and IEDs share common:
  - Protocols
  - Data Format and Context
  - Data Addressing/naming Conventions
  - Configuration Language
- RTUs become data concentrators that mirror IED data to higher level systems without complex configuration.

Legacy SCADA View of Data

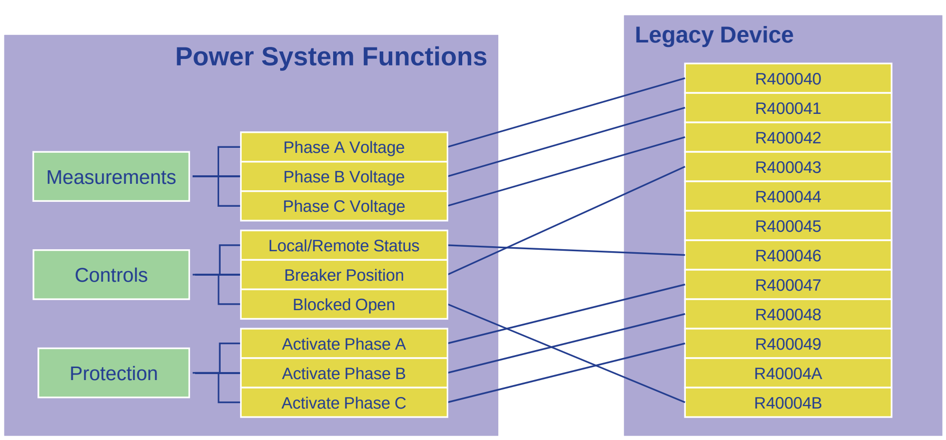


Legacy Data Access by Tag



Legacy Object Mapping

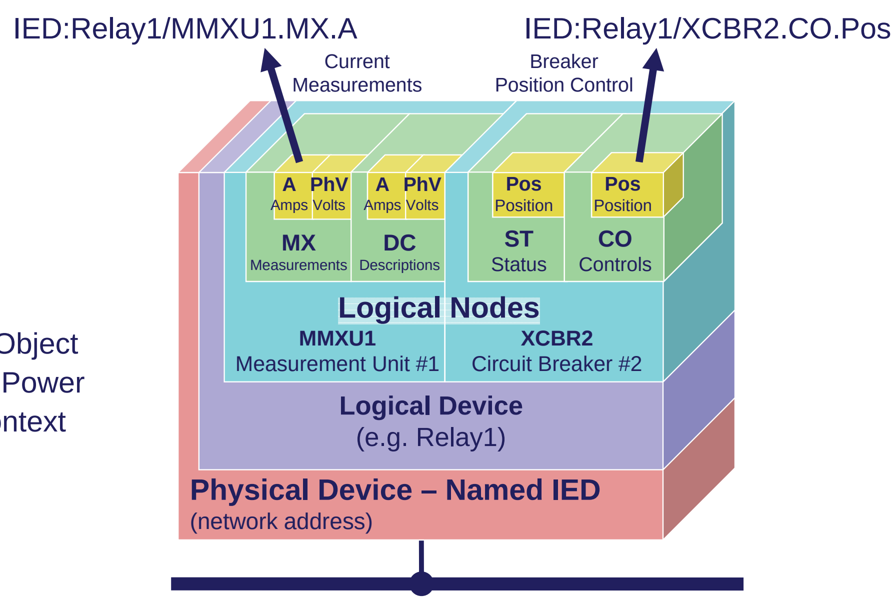
- Legacy data objects must be manually mapped to power system for each different device, application, and vendor.



Legacy View of Data

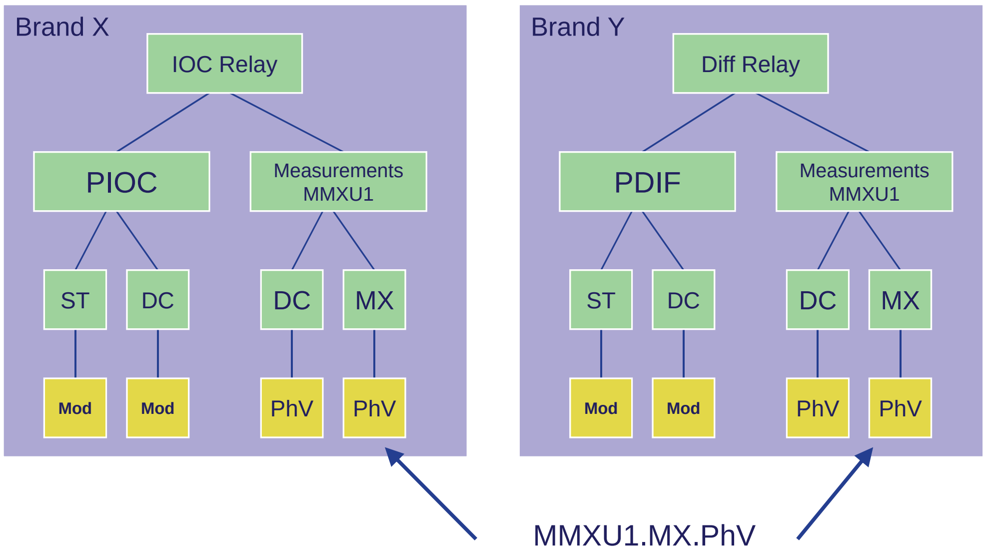
- Proprietary tag formats.
- Arcane addressing:
  - Driver
  - Wire
  - Rack
  - Device Register/Index #
  - Network
- **Manually entered.**
- **Manually verified.**
- Applications tied to tag or free form alias.
- Any user tag conventions are proprietary.

Anatomy of an IEC61850 Object Model



IEC 61850 Object Names Use Power System Context

IEC61850 View of Devices



MMXU1.MX.PhV
IEC61850 Name for Phase-to-Ground Voltage Measurements

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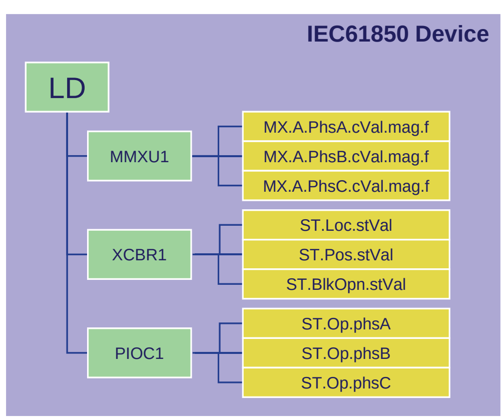
IEC 61850 Object Mapping

- **NO MANUAL MAPPING NEEDED**: IEC61850 objects already portray the power system context.



IEC61850 View of Devices

- Only network addressing requires configuration in the remote client.
- Point names portray the meaning and hierarchy of the data with no mapping to I/O required.
- Point names can be retrieved from the device automatically without manual intervention.
- All devices share a common naming convention.
- Device configurations can be exchanged using IEC61850-6-1 (SCL) files

More on SCL (IEC61850-6)

- SCL – Substation Configuration Language a standardized method of describing
  - Substation power systems
  - Device configuration
- SCL can be used to **unambiguously** describe user requirements for systems and devices.
- SCL can be used to configure applications without connecting to devices.
- SCL enables third party tools for configuration promoting choice and flexibility.
- Enables a model-driven approach to power system engineering that preserves system knowledge and applies it to reducing configuration and commissioning costs.

Benefits

- Reduced configuration costs:
  - Eliminates most manual configuration via automatic point name retrieval from devices
  - Common naming and object models eliminates ambiguity and manual mapping of data points.
- Equipment migrations occur with minimal impact on applications.
- Application changes have minimal effect on devices, network or other applications.
- Users can specify equipment more precisely eliminating delays and costly rework.
- Adapting SCL into the engineering process enables more effective design and commissioning resulting in higher productivity and higher value to the enterprise.

Justification

Description	Legacy	IEC61850	Impact
Equipment Purchase	$	$$	-
Installation	$$	$	+
Configuration	$$$	$	+
Equipment Migration	$$$	$	+
Engineering & Design	$$$	$	+

Small Co-op Experience

- Substation Modernization Pilot did 2 substations
  - DNP3.0 over TCP and UDP
  - IEC 61850
- Time to get DNP3 relay communicating: ~ 1 day
- Time to get IEC61850 relay communicating: **20 minutes**

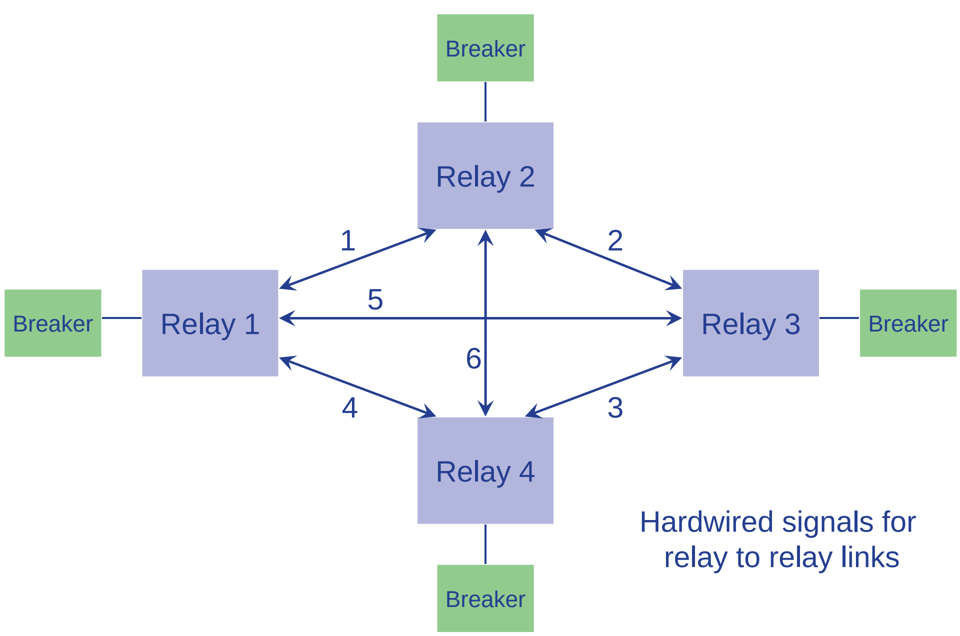
Large Midwestern Utility

- Using Legacy Protocols:
  - Significant more manpower to configure/install an relays using legacy RTU protocols.
- Using IEC61850:
  - Press a button and retrieve the point list from the devices….no need for an RTU.
  - Higher performance, more automation, better protection
  - Network devices and configuration at much lower cost.
  - **Instead of spending time configuring relays they are automating more substations.**

Relay to Relay Applications

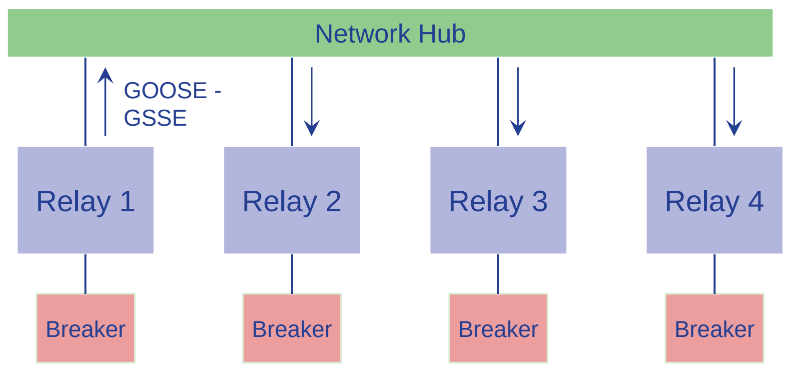
Protection Messaging
a.k.a. "Peer-to-Peer messaging"

Legacy Hardwired Architecture



Hardwired signals for relay to relay links

IEC61850 Network Architecture



GOOSE - Generic Object Oriented Substation Event (data sets)
GSSE – Generic Substation Status Event (status)

IEC61850 Network Architecture

- Relays share a common network making sophisticated protection schemes possible **even across very large distances**.
- Number of links for N relays is N and shared with SCADA.
- Relays send their status to all other relays at once using GOOSE.
- Status exchanged continuously.
- High performance.

Benefits

- Reduction of wiring costs
- More flexible programming is independent of wiring
- Reliability: Link status known before use.
- New capabilities not cost-effective with hardwired systems.
- Higher performance with more data.

Justification

Description	Legacy	IEC61850	Impact
Equipment Purchase	$	$$	-
Installation	$$$	$	+
Programming	$	$	0
Protection changes	$$$	$	+
Flexibility	$$$	$	+

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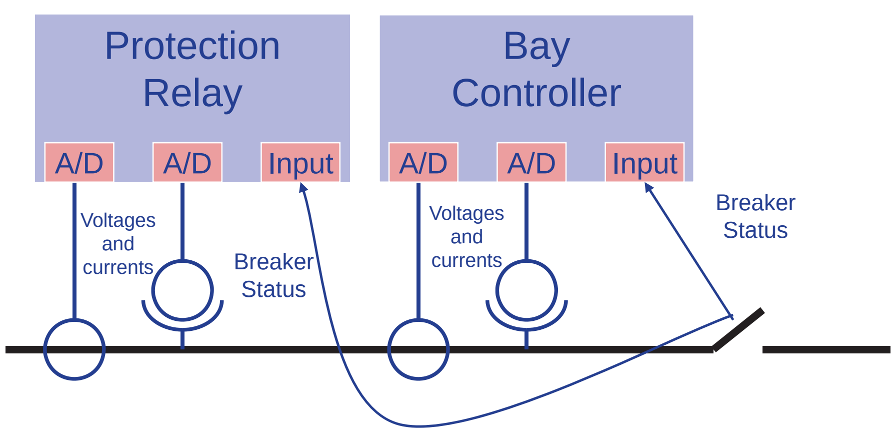
Transducer Interfaces

Process Bus

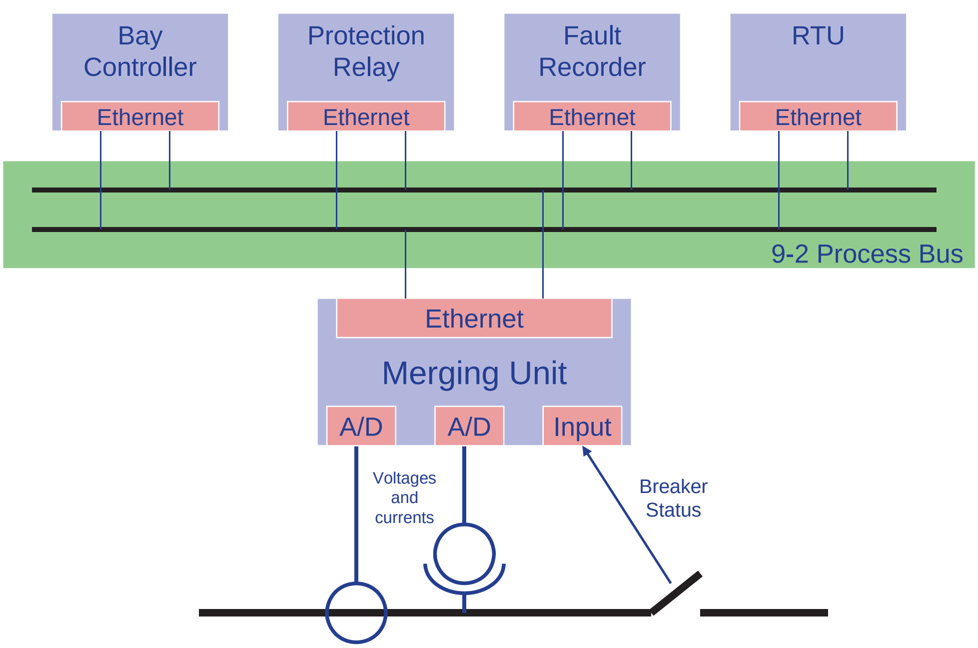
Legacy Approach



Legacy Approach

- Individually and redundantly wired to all devices needing the same signals:
  - CTs
  - PTs
  - Status Inputs
  - Outputs
- Each individual sensor must be calibrated and maintained separately.
- Incremental cost is exponential (signals x devices)
- Result is minimization of I/O
- Analog signal wiring constraints

IEC61850 Approach



IEC61850-9-2 Process Bus

- Transducer and I/O signals are shared via a network.
- Only one transducer or I/O point per signal.
- Minimization of calibration and maintenance.
- Incremental cost is linear (signals only)
- CT/PT signals can be sent across long distances
- Future: Integrated merging unit with digital fiber optic transducers

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Justification

Description	Legacy	IEC61850	Impact
Equipment Purchase	$$	$	+
Installation	$$$	$	+
Configuration	$$	$	+
Flexibility	$$$	$	+

Conclusion

- IEC61850 substation architectures provide significant benefits to users.
- Key intangible: flexibility to accomplish new objectives that are too costly (or not possible) with legacy technology.
- Justification is challenging but realistic.

Questions - Discussion

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IEC61850 Summary

What is IEC61850?

A comprehensive standard for the application of modern networking technology to electric power substation automation including:

- Requirements
- Configuration
- Protocols
- Testing

- Highly functional supporting most useful power system functions.
- Object oriented standardized device and object models and naming conventions.
- Self-describing devices allow all object definitions to be retrieved over the wire.
- Standardized configuration language.
- Uses Ethernet and TCP/IP networking.

Why is IEC 61850 Different?

If adapted fully, IEC 61850 is a new process for substation automation and engineering that is designed to lower costs of engineering, implementation, and maintenance of substation systems.

IEC 61850 is Growing

- IEC 61400-25 Wind Power
- IEC 61850-7-410 Hydro Power
- IEC 61850-7-420 Distributed Energy Resources
- IEC 61850 -80-1 Gateway mapping to IEC 60870-5-101/104
- IEC 61850-90-1 Using IEC 61850 between substations
- IEC 61850-90-2 Using IEC 61850 from control center to substation
- IEC 61850-90-5 GOOE and Process Bus over IP Multicast for Synchrophasor Communications (including certificate distribution)

New Name for IEC 61850

- Edition 2 of IEC 61850 is renamed:

Communication Networks And Systems For Power Utility Automation

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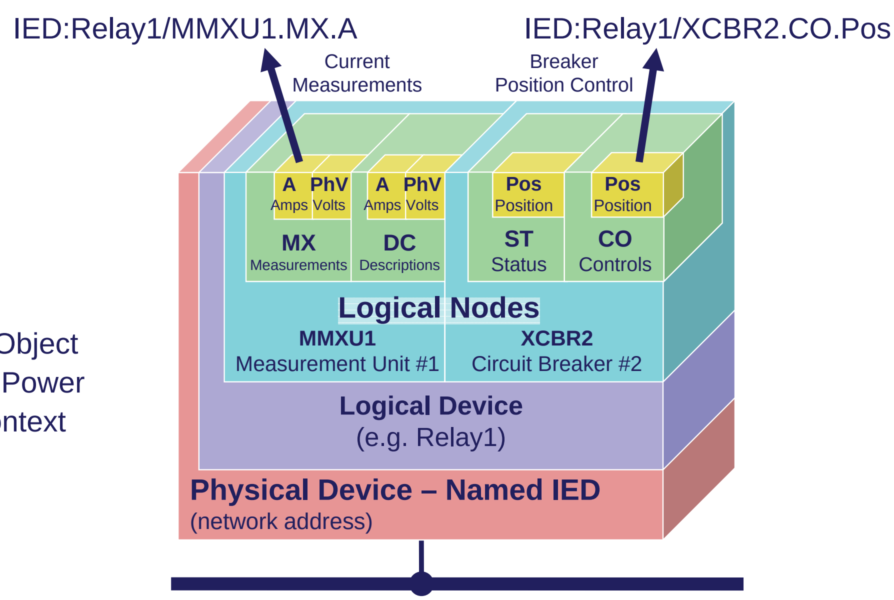
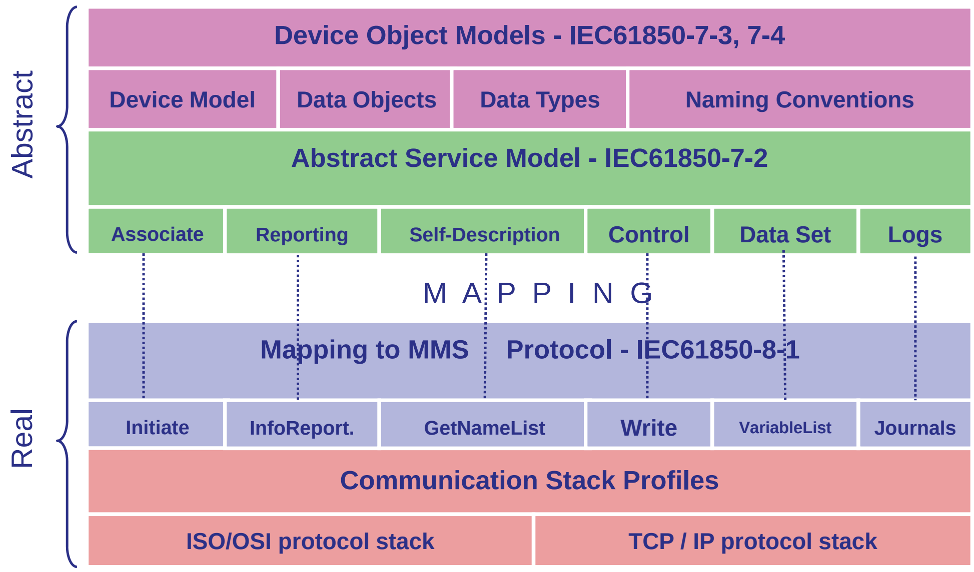
IEC61850 Data Model



IEC 61850 Object Names Use Power System Context

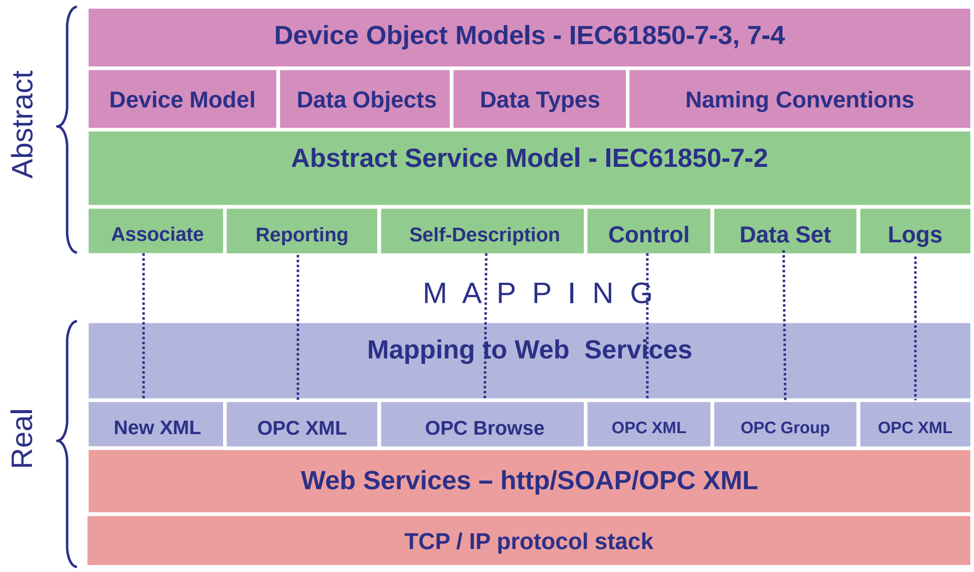
IEC61850 – Layered Standard



Benefits of Abstraction and Layering

- Abstract models are independent of the protocol and can be used outside of protocol applications (SCADA tag naming convention)
- Enables definition beyond just the bytes on the wire to incorporate naming and behavior
- Each layer can be optimized independently
- Enables protocols to be separated from application functions to enable use of existing standards (Ethernet, TCP/IP, etc.)
- Enables use of the abstract concepts to other protocols/systems in the future as technology changes.

Other Protocol Mappings Possible



Why MMS for IEC61850-8-1

- Real-time control needs more robust and higher performance communications than offered by http and XML.
- MMS was ahead of its time in 1988. MMS remains the only standardized protocol specification capable of supporting the IEC 61850 requirements for service, complex named data, and performance.

MMS

- Manufacturing Message Specification
  - ISO 9506
  - Developed in 1988 by ISO TC184
  - Originally developed for industrial automation
  - V2002 of MMS is used for IEC 61850
    - Larger Object Names
    - Eliminated restrictions on Journals (logs)
    - UTC time format
- Supervisory control and real-time data access

MMS Objects

- Virtual Manufacturing Device (**VMD**) – A server that contains objects
- **Variable** – Named complex variables that are self describing.
- **Named Variable List** (NVL) – A collection of variables
- **Domain** – A resource that may contain other objects.
- **Journal** – A time based record of variables.

Basic MMS Services

- Associate/Conclude/Abort
  - Make/break connections between client and server
- Read/Write
  - Variables and NVL
- InformationReport
  - Send an unsolicited Read response to a client
- ReadJournal
  - Query a historical log of variable data
- GetNameList/GetObjectAttributes
  - Get the definition of an object

IEC 61850 Features

- Client Server Communications:
  - Clients can retrieve all data object definitions and device behavioral information over the wire with minimal configuration
  - Simple and complex data access using standardized object names using power system context for the majority of substation functions required.
  - Named data sets to collect data elements into groups for reporting.
  - Buffered and Unbuffered report by exception of Data Sets configurable by clients via named control blocks.
  - Comprehensive control modes including direct and SBO with or without enhanced security.
  - Logs for event data with configurable access by clients via named control blocks.
  - Named control blocks for clients to control multi-cast messaging (GOOSE)
  - Named control blocks for clients to control process bus messaging of sampled values
  - Settings group controls via named control blocks enabling client control of settings.
  - Substitution functions enabling clients to override values for status and measurements.

IEC 61850 Features

- Multi-cast messaging enables devices to broadcast status, control, and I/O information to many devices simultaneously:
  - Generic Substation Status Event (GSSE) supports distribution of 2-bit status information over the station bus.
  - Generic Object Oriented Status Event (GOOSE) supports distribution of a user defined data sets over the station bus. Typically user configurable in the device.
  - Sampled Values (SV) supports distribution of time sampled data such as measurements, status, and other I/O signals over a separate “process bus”
  - Unicast services for these functions enable verification and discovery of the data contained in the multi-cast messages without requiring client/server communications.
- **Standardized XML based substation configuration language (SCL) for exchange of power system and device configuration information using a standard format. IEC 61850-6**

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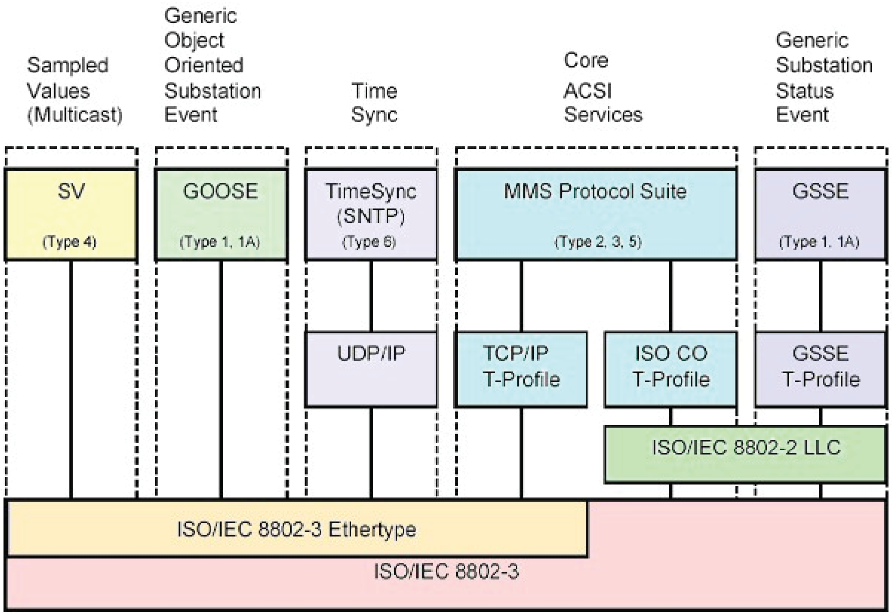
IEC 61850 Profiles

IEC 61850 Ed. 1 Profiles



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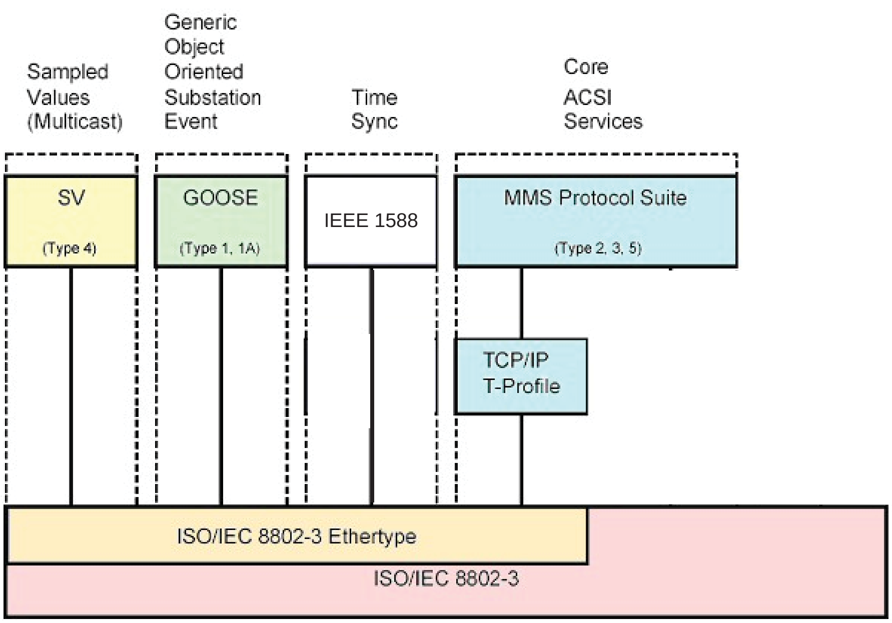
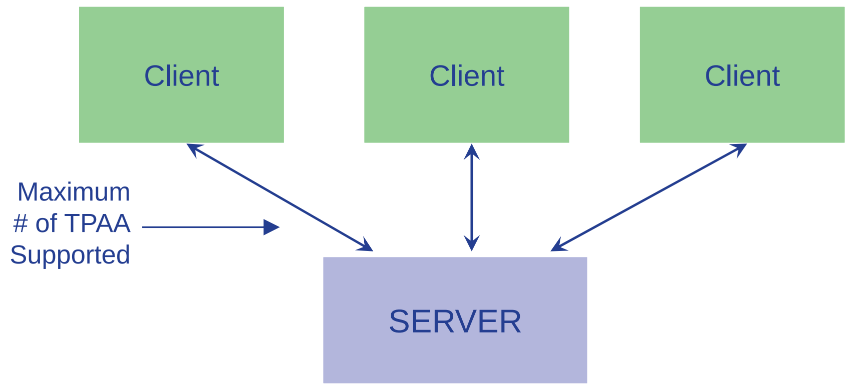
IEC 61850 Profiles – Ed.2



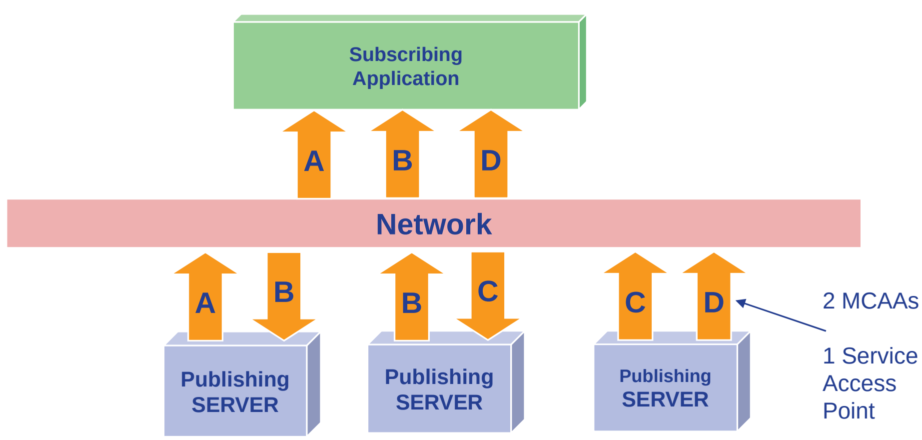
Two Party Application Association



Service	Description
Associate	Establish an association
Abort	Abort an association
Release	Release an association

From IEC61850-7-2

Multi-Cast Application Association



Service: send Data (unconfirmed)

Some Terms

- Network Access Methods:
  - Master Slave – a master controls slave access to the network (e.g. DNP3)
  - Peer-to-peer – any entity may send data to any other peer entity on the network without having to coordinate with a master (TCP/IP-Ethernet).
- Client-Server – defines roles between 2 peers on a network.

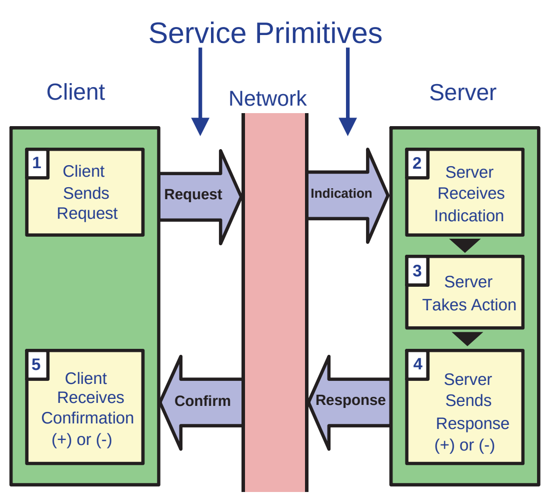
Client/Server Architecture

Server:

- A device or application that maintains data objects and performs operations on behalf of clients.
- Service primitives: **Indication** and **Response**.

Client:

- A networked application or device that asks for data or an action from the server.
- Service primitives: **Request** and **Confirmation**.



Request – Indication are identical
Response – Confirmation are identical
} Differ only in direction

Unconfirmed Service

- A “Report” is when a server sends data without a client request.
- In IEC 61850-8-1 reports are mapped to the MMS InformationReport service
  - InformationReport is essentially a way to send the data from a Read response without the client having to ask for it

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IEC 61850 and Ethernet

Brief Overview of Ethernet for IEC 61850

Ethernet and the 7 (9) Layer Model

- 9. Environment (Power Systems)
- 8. User (IEC 61850)
- 7. Application (MMS)
- 6. Presentation
- 5. Session
- 4. Transport
- 3. Network
- 2. Data Link
- 1. Physical

Logical Link Control (LLC)
EtherType

Media Access Control (MAC)
IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

Network Media

Ethernet Physical Layer Standards

10BaseT - Twisted pair - CAT 5 cable (IEEE 802.3)

10BaseFl - Multi-mode fiber (IEEE 802.3) @ 850nm

10Base2 - Thin wire coax (IEEE 802.3)

10Base5 - Thick wire coax (IEEE 802.3)

100BaseTx - Twisted pair CAT 5 cable (IEEE 802.3u)

100BaseSx – Multi-mode fiber @ 850nm

100BaseT4 - Twisted pair CAT 3 cable (IEEE 802.3u)

100BaseFx - Multi-mode fiber @ 1330nm (IEEE 802.3u)

1000BaseF - Multi-mode fiber (IEEE 802.3z and ab) – Gig-E

10000BaseF - Multi-mode fiber (IEEE 802.3ae)

Numerous others and more coming all the time – IEC 61850 is flexible to accommodate them

Redundant Port Implementations

Redundant Port: 2 independent Ethernet ports with 2 different addresses

MAC – 1
IP Addr - 1

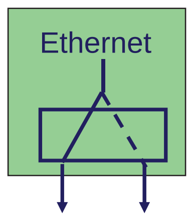
Ethernet1

Ethernet2

MAC – 2
IP Addr - 2

Redundant Media: 1 Ethernet port with switched media

MAC – 1
IP Addr - 1



Switches on loss of Ethernet link pulses

Primary **Back-Up**

Redundant Media is Common - Easy to Configure for Redundancy

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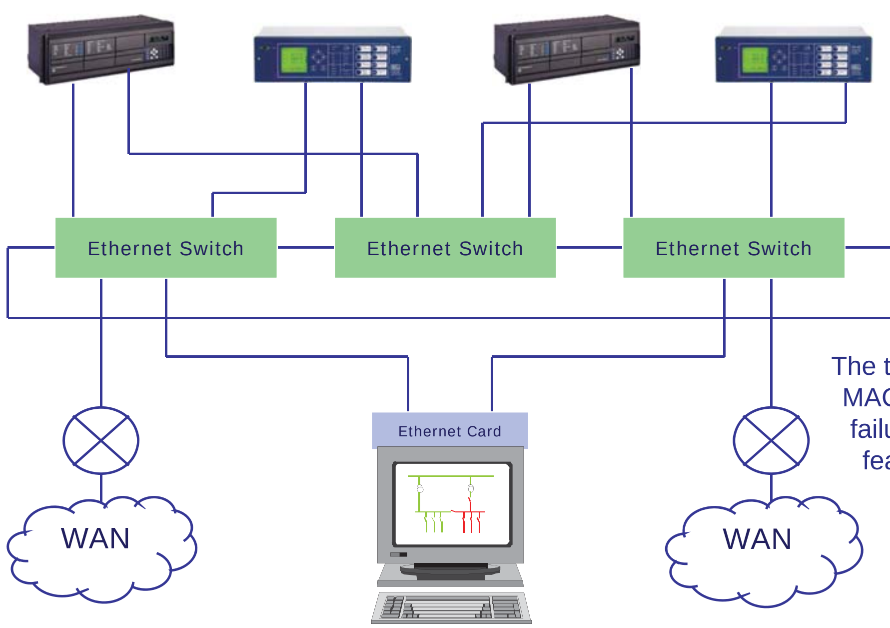
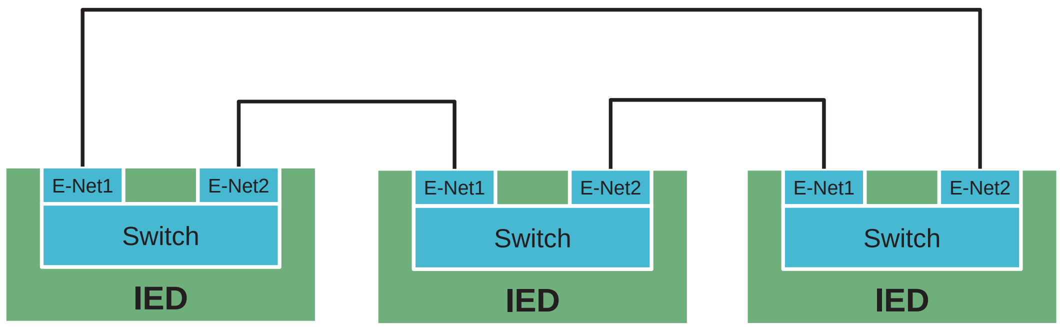
Redundant Network Configuration



The time to rebuild MAC tables after failure is critical feature of the switches

Emerging Approach – Embedded Switching



HSR – High-Speed Redundancy Ethernet uses this kind of approach to avoid the delay of rebuilding the MAC tables on a failure

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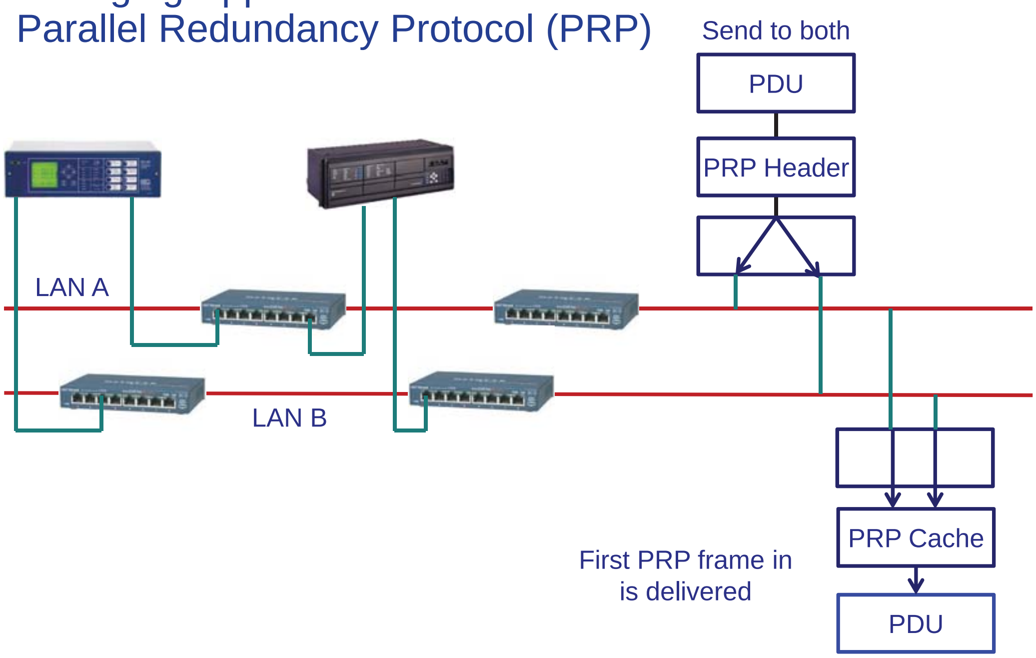
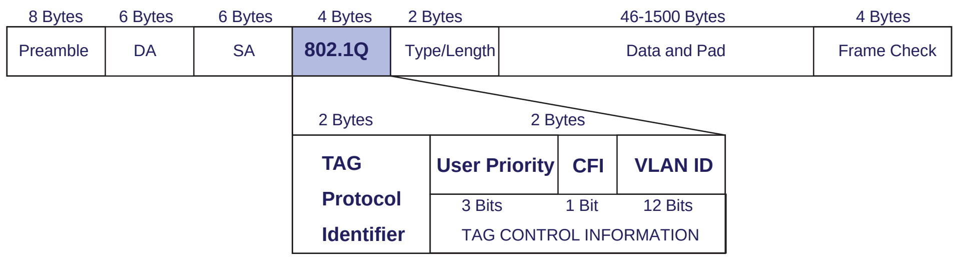
Emerging Approach – Parallel Redundancy Protocol (PRP)



EtherType Packet Structure used by GOOSE



- 4 bytes added to the Ethernet frame
- Tag Protocol Identifier (TPID) set to 8100 hex …identifies an 802.1Q message type
- 12 bits used for VLAN Identifier
- 3 bits used for Priority – 8 levels
- CFI = 0 for Ethernet

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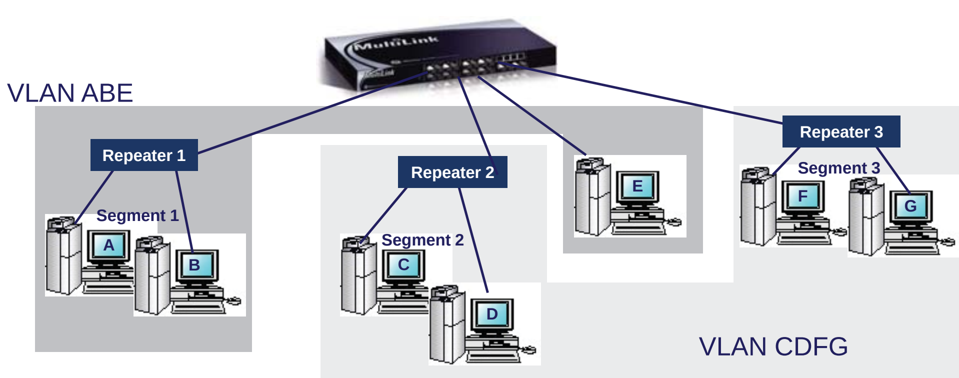
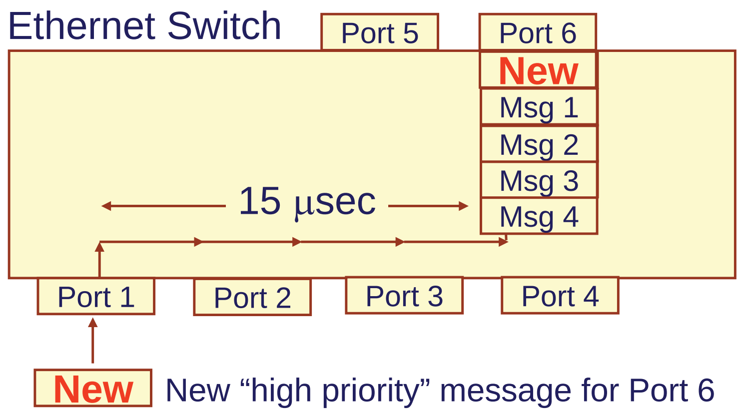
VLANs

- VLANs: Are logical groupings of nodes that reside in a common broadcast domain
  - Virtual because the VLAN is artificially created and the nodes need not be physically located on the same switch or even reside in the same building, but
    - Nodes that are members behave like they are connected together by one layer 2 bridge or switch
    - A router is required to communicate between the two VLANs



Ethernet Priority

- Ethernet 802.1q provides a priority setting
- “High” priority messages are moved to the priority queue
- Specified in IEC GOOSE and Implemented in GE Multilink Switch



Courtesty of GE Multilin

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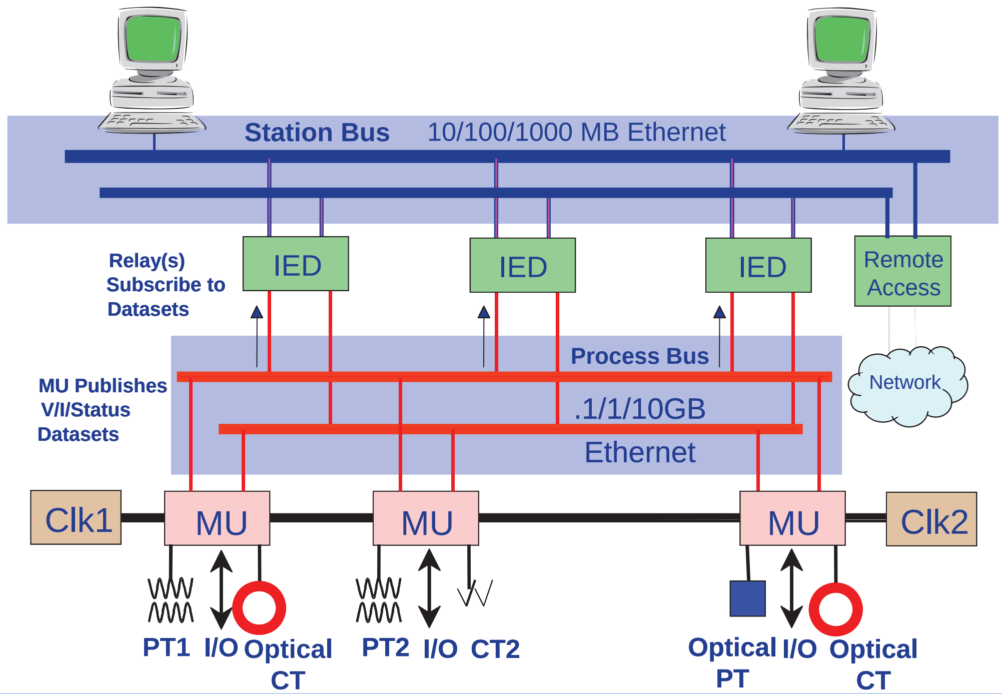
IEC 61850 Standard and Object Models

IEC61850 Substation Architecture



MU = Merging Unit

IEC61850 Base Standard

Basic principles		Part 1
Glossary		Part 2
General Requirements		Part 3
System and project management		Part 4
Communication requirements		Part 5
Substation Automation System Configuration		Part 6
Basic Communication Structure		Part 7
Part 8: Mapping to MMS and Ethernet	Sampled Measured Values / Mapping to Ethernet	Part 9
Conformance testing		Part 10

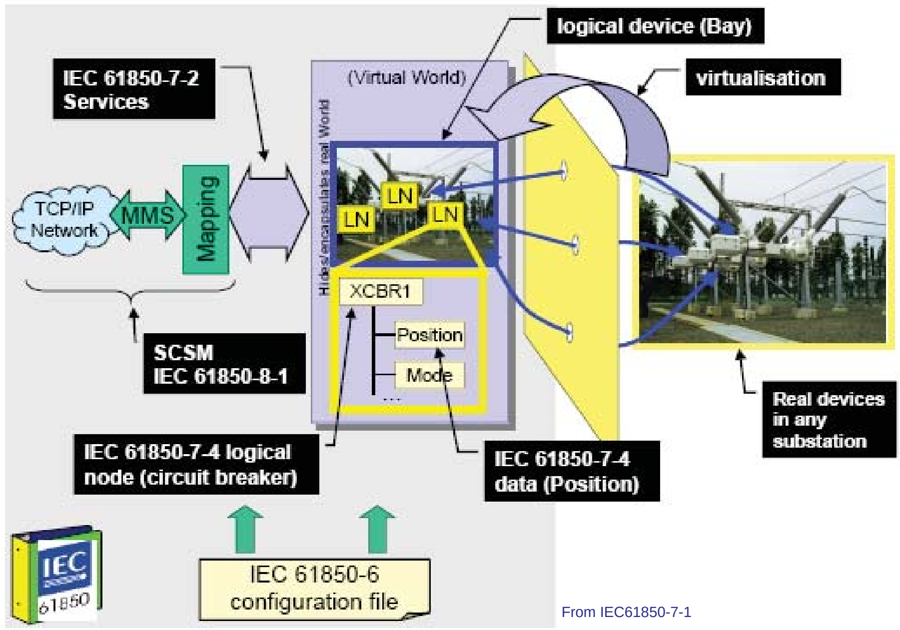
IEC 61850 Standard Extensions

- IEC 61850-7-4XX: Extensions for a specific application
  - IEC 61850-7-410: Hydropower
  - IEC 61850-7-420: Distributed Energy Resources
- IEC 61850-80-X: Permanent Technical Reports
  - IEC 61850-80-1: Mapping IEC 60870-5-101/104 to IEC 61850
- IEC 61850-90-X: Future extensions to base IEC 61850 standards
  - Issued as technical reports outside of the normal revision cycle for the IEC 61850 base standard.
  - Specify future enhancements to the base and enables early adaption without having to wait for the base to be updated.
  - IEC 61850-90-1 Using IEC 61850 between substations
  - IEC 61850-90-2 Using IEC 61850 from control center to substation
  - IEC 61850-90-5 GOOE and Process Bus over IP Multicast

IEC61850 – Communications Parts

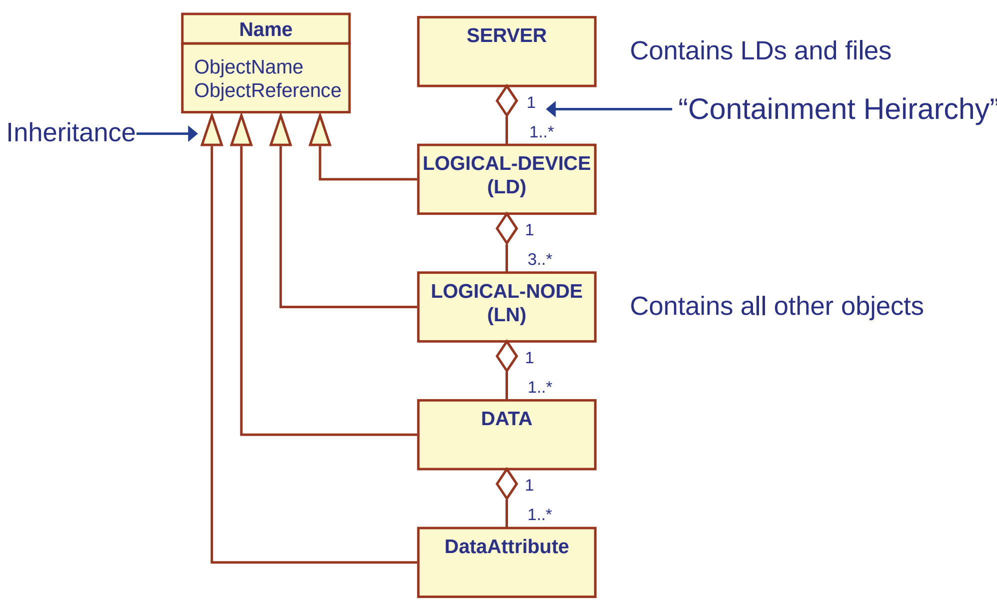
- Part 6: Substation Configuration Language (**SCL**)
- Part 7-2: Abstract Communications Service Interface (**ACSI**) and base types
- Part 7-3: Common Data Classes (**CDC**)
- Part 7-4: Logical Nodes (**LN**)
- Part 7-4XX: Other LNs and CDCs
- Part 8-1: Specific Communications Service Mappings (**SCSM**) - MMS & Ethernet
- Part 9-2: SCSM - Sampled Values over Ethernet
- Part 10-1: Conformance Testing

IEC61850 Virtual Model



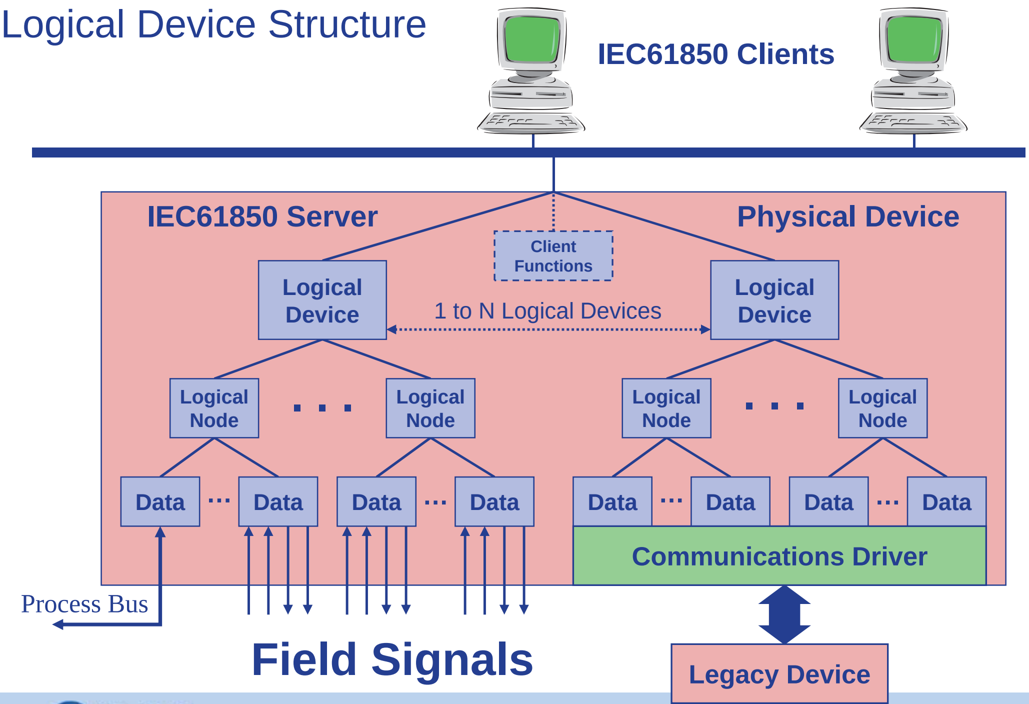
From IEC61850-7-1

IEC61850 Class Model in UML



UML – Unified Modeling Language

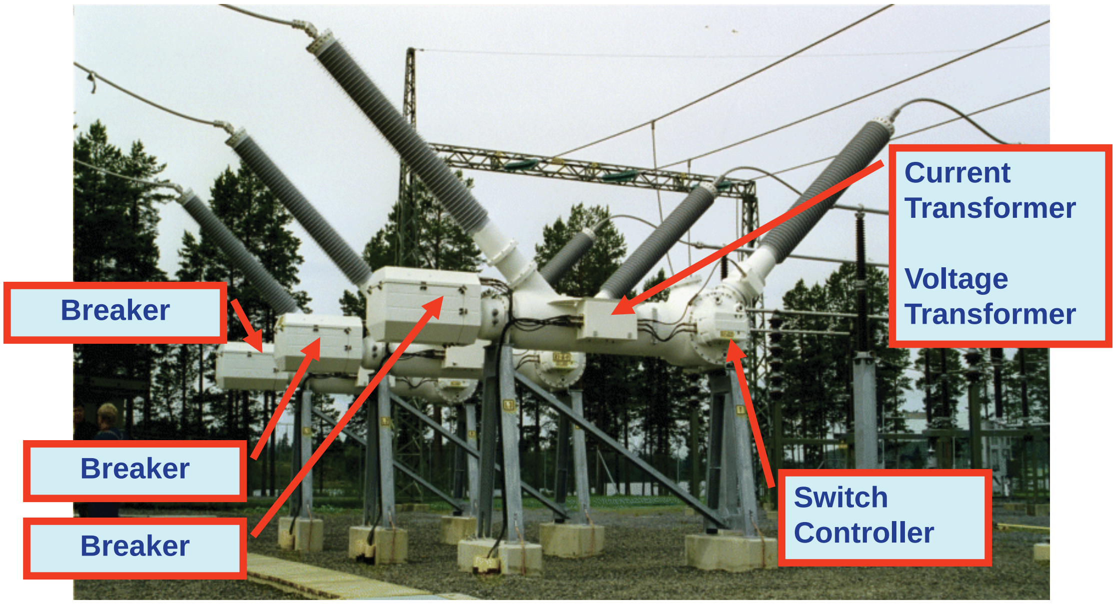
Logical Device Structure



Logical Node

A named grouping of data and associated services that is logically related to some power system function.

Examples of Logical Nodes



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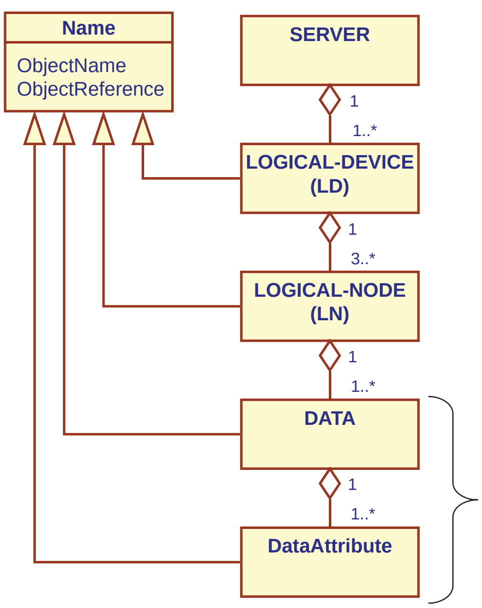
Logical Nodes Contain Data



We are going to start from the bottom up and build up the logical node definitions starting with Common Data Classes (CDC) and their attributes.

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Common Data Classes

CDC

Common Data Classes (CDC)

- Defines structure for common types that are used to describe data objects.
- CDC are complex objects built on predefined simple base types organized into functional constraints (FC)
- Examples:
  - Single point status (SPS) – on/off
  - Double point status (DPS) – on/off/transient

IEC61850 Base Types

Name	Value Range
BOOLEAN	True/False
INT8	-128 to 127
INT16	-32,768 to 32,767
INT24	-8,388,608 to 8,388,607
INT32	-2,147,483,648 to 2,147,483,647
~~INT128~~ INT64	~~-2**127 to (2**127)-1~~ -2**63 to (2**63)-1
INT8U	0 to 256 – unsigned integer
INT16U	0 to 65,535 – unsigned integer
INT24U	0 to 16,777,215 – unsigned integer (fractions of second)
INT32U	0 to 2,294,967,295 – unsigned integer
~~INT64U~~	~~For Accumulators (V2)~~
FLOAT32	IEEE 754 single precision floating point
~~FLOAT64~~	~~IEEE 754 double precision floating point~~
ENUMERATED	Ordered set of values, defined where used
CODED ENUM	Ordered set of values, defined where used
OCTET STRING	Sequence of bytes (octets) max length defined where used
VISIBLE STRING	Visible string (ASCII)
UNICODE STRING	Unicode string (for non-latin languages)

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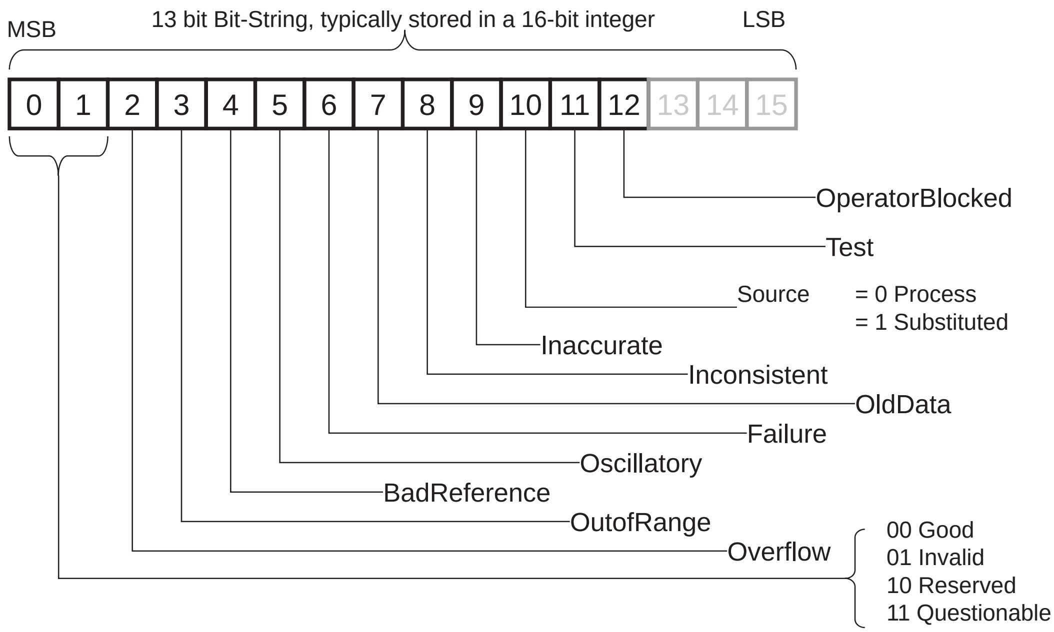
IEC 61850 TimeStamp Format – GMT

- 4 Bytes = Second Of Century (SOC) Starting January 1, 1970
  - Based on the Network Time Protocol (NTP) standard
  - There are 31,536,000 seconds/year (non-leap)
  - 4 bytes = 4, 294,967,296 counts do not wrap for 136 years or 2106
- 3 Bytes = Fraction of Second
  - 16,777,216 counts
  - about 60nsec potential resolution
- 1 Byte = Quality
  - 1 bit : Leap Seconds known
  - 1 bit : ClockFailure
  - 1 bit : ClockNotSynchronized
  - 5 bits: TimeAccuracy - Number of significant bits in Fraction of Second (N)

IEC 61850 Time Accuracy

Class	Accuracy	Time Accuracy (N bits)
T0	± 10 ms	N=7
T1	± 1 ms	N=10
T2	± 0.1 ms	N=14
T3	± 25 μsec	N=16
T4	± 4 μsec	N=18
T5	± 1 μsec	N=20
`**unspecified**		N=31

IEC 61850 Quality



Common Data Classes - Status

Name	Description
SPS	Single Point Status
DPS	Double Point Status
INS	Integer Status
ENS	Enumerated Status
ACT	Protection Activation
ACD	Directional Protection Activation Info.
SEC	Security Violation Counting
BCR	Binary Counter Reading
HST	Histogram
VSS	Visible String Status

Edition 2 (ENS, HST, VSS)

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Common Data Classes - Measurands

Name	Description
MV	Measured Value
CMV	Complex Measured Value
SAV	Sampled Value
WYE	Phase to ground measured values for 3-phase system
DEL	Phase to phase measured values for 3-phase system
SEQ	Sequence
HMV	Harmonic value
HWYE	Harmonic value for WYE
HDEL	Harmonic value for DEL

Common Data Classes - Controls

Name	Description
SPC	Controllable Single Point
DPC	Controllable Double Point
INC	Controllable Integer Status
ENC	Controllable Enumerated Status
BSC	Binary Controlled Step Position Info.
ISC	Integer Controlled Step Position Info.
APC	Controllable Analogue Process Value
BAC	Binary Controlled Analog Process Value

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Common Data Classes – Settings and Descriptions

Name	Description
SPG	Single Point Setting
ING	Integer Status Setting
ENG	Enumerated Status Setting
ORG	Object Reference Setting
TSG	Time Setting Group
CUG	Currency Setting Group
VSG	Visible String Setting
ASG	Analogue Setting
CURVE	Setting Curve
CSG	Curve Shape Setting
DPL	Device Name Plate
LPL	Logical Node Name Plate
CSD	Curve Shape Description

Common Data Classes – Control Block Service Tracking

Name	Description
CTS	Common Service Tracking
BTS	Buffered Report Tracking Service
UTS	Unbuffered Report Tracking Service
LTS	Log Control Block Tracking Service
GTS	GOOSE Control Block Tracking Service
MTS	Multicast Sampled Value (9-2) Control Block Tracking Service
NTS	Unicast Sample Value (9-1) Control Block Tracking Service
SGCB	Setting Group Control Block Tracking Service

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Functional Constraints

- There are many data attributes in an object like a breaker that have related use
  - Control, configuration, measurement, reporting, etc.
- Functional Constraints (FC) is a property of a data attribute that characterizes the specific use of the attribute.
- Useful to functionally organize data attributes to provide structure and context.

Functional Constraints

FC Name	Description
ST	Status Information
MX	Measurands (analog values)
CO	Control
SP	Set point (settings outside setting groups)
SV	Substituted Values
CF	Configuration
DC	Description
SG	Setting Group
SE	Setting Group Editable
SR	Service Response
OR	Operate Received
BL	Blocking
EX	Extended Definition (naming – read only)
BR	Buffered Report
RP	Unbuffered Report
LG	Logging
GO	GOOSE Control
GS	GSSE Control
MS	Multicast Sampled Value (9-2)
US	Unicast Sampled Value (9-1)
XX	Used as wild card in ACSI

Replaced with Control Block Service Tracking CDCs in 7-2
8-1 reinserted for mapping to MMS
(BR, RP, LG, GO, GS, MS, US)

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Single Point Status (SPS)

SPS class					
Data Attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
status					
stVal	BOOLEAN	ST	dchg	TRUE | FALSE	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	BOOLEAN	SV		TRUE | FALSE	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 2 (blkEna)

Attribute Name | Type | Functional Constraint | Trigger Options | Range of Values | Mandatory/ Optional

Trigger Option (TrgOp)

Specifies the conditions under which reporting on the data attribute can be triggered.

TriggerConditions type				
Attribute name		Attribute type	Value / Value Range	M/O/C
		PACKED LIST		M
	data-change	BOOLEAN	See Clause **Error! Reference source not found.**	M
	quality-change	BOOLEAN	See Clause **Error! Reference source not found.**	M
	data-update	BOOLEAN	See Clause **Error! Reference source not found.**	M
	integrity	BOOLEAN	See Clause **Error! Reference source not found.**	M
	general-interrogation	BOOLEAN	See Clause **Error! Reference source not found.**	M

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Logical Node Name Plate - LPL

LPL class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
configuration, description and extension					
vendor	VISIBLE STRING255	DC			M
swRev	VISIBLE STRING255	DC			M
d	VISIBLE STRING255	DC			O
dU	UNICODE STRING255	DC			O
configRev	VISIBLE STRING255	DC			AC_LN0_M
paramRev	INT32	ST	dchg		O
valRev	INT32	ST	dchg		O
ldNs	VISIBLE STRING255	EX		shall be included in **LLN0** only; for example "IEC 61850-7-4:2003"	AC_LN0_EX
lnNs	VISIBLE STRING255	EX			AC_DLD_M
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 2 (paramRev, valRev)

Configuration Revision Parameters

- configRev – Changed whenever at least on semantic aspect of the data has changed within the Logical Device (LD) within which this LLN0 is contained. Left to the “user” (vendor) for other LNs.
  - New LNs
  - New attributes.
- paramRev – Changed when the value of any editable setting (SE) or setpoint (SP) parameter is changed.
  - If changed via communications or local HMI the value is increased by 1.
  - If changed via SCL import the value is increased by 10,000.
- valRev – changed when the value of any configuration (CF) parameter is changed.
  - If changed via communications or local HMI the value is increased by 1.
  - If changed via SCL import the value is increased by 10,000.

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Device Name Plate - DPL

DPL class					
Data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
				configuration, description and extension	
vendor	VISIBLE STRING255	DC			M
hwRev	VISIBLE STRING255	DC			O
swRev	VISIBLE STRING255	DC			O
serNum	VISIBLE STRING255	DC			O
model	VISIBLE STRING255	DC			O
location	VISIBLE STRING255	DC			O
name	VISIBLE STRING64	DC			O
owner	VISIBLE STRING255	DC			O
ePSName	VISIBLE STRING255	DC			O
primeOper	VISIBLE STRING255	DC			O
secondOper	VISIBLE STRING255	DC			O
latitude	FLOAT32	DC			O
longitude	FLOAT32	DC			O
altitude	FLOAT32	DC			O
mrID	VISIBLE STRING255	DC			O
d	VISIBLE STRING255	DC			O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 2 (rows name through dU)

Lat/Long in WGS84 coordinates

Substitution

SPS class					
Data Attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
				status	
stVal	BOOLEAN	ST	dchg	TRUE | FALSE	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
				substitution and blocked	
subEna	BOOLEAN	SV			PICS_SUBST
subVal	BOOLEAN	SV		TRUE | FALSE	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
				configuration, description and extension	
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

- Substitution enables value and quality to be overridden by a local process or by an operator identified by subID.
- Status or measured values only. Not applicable to sampled values.
- Substition is reflected in the quality (q) of the original value.

Double Point Status (DPS)

DPS class					
Data Attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
				status	
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
				substitution and blocked	
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
				configuration, description and extension	
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 2

2-bit pair in DPS versus boolean in SPS

Visible String Status – VSS (Edition 2)

VSS class					
Data Attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
				status	
stVal	VISIBLE STRING 255	ST	dchg	Text	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
				configuration, description and extension	
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

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Controllable Double Point – DPC (Edition 1)

DPC class					
Attribute Name	**Attribute Type**	**FC**	**TrgOp**	**Value/Value Range**	**M/O/C**
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute					From IEC61850-7-3
				control and status	
ctlVal	BOOLEAN	CO		off (FALSE) | on (TRUE)	AC_CO_M
operTm	TimeStamp	CO			AC_CO_O
origin	Originator	CO, ST			AC_CO_O
ctlNum	INT8U	CO, ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		AC_CO_O
				substitution	
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
				configuration, description and extension	
pulseConfig	PulseConfig	CF			AC_CO_O
ctlModel	CtlModels	CF			M
sboTimeout	INT32U	CF			AC_CO_O
sboClass	SboClasses	CF			AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Mandatory if control is supported

Optional if control is supported

Controllable Double Point DPC (Edition 2)

Edition 2 (opRcvd, opOk, tOpOk)

Edition 2 (blkEna)

Edition 2 (operTimeout)

DPC class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
status and control mirror					
origin	Originator	ST			AC_CO_O
ctlNum	INT8U	ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		O
opRcvd	BOOLEAN	OR	dchg		O
opOk	BOOLEAN	OR	dchg		O
tOpOk	TimeStamp	OR			O
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
pulseConfig	PulseConfig	CF	dchg		AC_CO_O
ctlModel	CtlModels	CF	dchg		M
sboTimeout	INT32U	CF	dchg		AC_CO_O
sboClass	SboClasses	CF	dchg		AC_CO_O
operTimeout	INT32U	CF	dchg		AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

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Controllable Double Point DPC ctlVal (Edition 2)

DataAttribute					
status and control mirror					
origin	Originator	ST			AC_CO_O
ctlNum	INT8U	ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		O
opRcvd	BOOLEAN	OR	dchg		O
opOk	BOOLEAN	OR	dchg		O
tOpOk	TimeStamp	OR			O
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
pulseConfig	PulseConfig	CF	dchg		AC_CO_O
ctlModel	CtlModels	CF	dchg		M
sboTimeout	INT32U	CF	dchg		AC_CO_O
sboClass	SboClasses	CF	dchg		AC_CO_O
operTimeout	INT32U	CF	dchg		AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table 31					

parameters for control services

Service parameter name	Service parameter type	Value/Value range
ctlVal	BOOLEAN	off (FALSE) | on (TRUE)

Controllable Integer Status - INC

Edition 2

INC class					
Data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
status and control mirror					
origin	Originator	ST			AC_CO_O
ctlNum	INT8U	ST		0..255	AC_CO_O
stVal	INT32	ST	dchg		M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		O
opRcvd	BOOLEAN	OR	dchg		O
opOk	BOOLEAN	OR	dchg		O
tOpOk	TimeStamp	OR			O
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	INT32	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
ctlModel	CtlModels	CF	dchg		M
sboTimeout	INT32U	CF	dchg		AC_CO_O
sboClass	SboClasses	CF	dchg		AC_CO_O
minVal	INT32	CF	dchg		O
maxVal	INT32	CF	dchg		O
stepSize	INT32U	CF	dchg	1 … (maxVal – minVal)	O
operTimeout	INT32U	CF	dchg		AC_CO_O
units	Unit	CF	dchg		O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 1

INC class		
Attribute Name	Attribute Type	FC
DataName	Inherited from Data Class (see IEC	
DataAttribute		
ctlVal	INT32	CO
operTm	TimeStamp	CO
origin	Originator	CO, ST
ctlNum	INT8U	CO, ST
stVal	INT32	ST
q	Quality	ST
t	TimeStamp	ST
stSeld	BOOLEAN	ST
subEna	BOOLEAN	SV
subVal	INT32	SV
subQ	Quality	SV
subID	VISIBLE STRING64	SV
configurat		
ctlModel	CtlModels	CF
sboTimeout	INT32U	CF
sboClass	SboClasses	CF
minVal	INT32	CF
maxVal	INT32	CF
stepSize	INT32U	CF
d	VISIBLE STRING255	DC
dU	UNICODE STRING255	DC
cdcNs	VISIBLE STRING255	EX
cdcName	VISIBLE STRING255	EX
dataNs	VISIBLE STRING255	EX

Controllable Integer Status – INC – ctlVal

DataAttribute					
status and control mirror					
origin	Originator	ST			AC_CO_O
ctlNum	INT8U	ST		0..255	AC_CO_O
stVal	INT32	ST	dchg		M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		O
opRcvd	BOOLEAN	OR	dchg		O
opOk	BOOLEAN	OR	dchg		O
tOpOk	TimeStamp	OR			O
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	INT32	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
ctlModel	CtlModels	CF	dchg		M
sboTimeout	INT32U	CF	dchg		AC_CO_O
sboClass	SboClasses	CF	dchg		AC_CO_O
minVal	INT32	CF	dchg		O
maxVal	INT32	CF	dchg		O
stepSize	INT32U	CF	dchg	1 … (maxVal – minVal)	O
operTimeout	INT32U	CF	dchg		AC_CO_O
units	Unit	CF	dchg		O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table 31					
parameters for control services					
Service parameter name	**Service parameter type**	**Value/Value range**			
ctlVal	INT32				

Control Model (ctlModel)

- 0: Status only. No control allowed.
- 1: Direct control with normal security
- 2: SBO control with normal security
- 3: Direct control with enhanced security
- 4: SBO control with enhanced security

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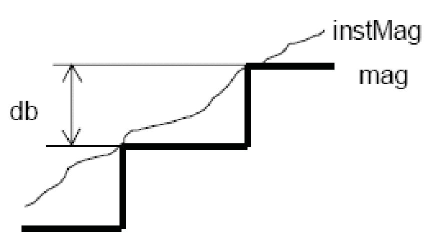
Ed. 2 Control Service Tracking

- opRcvd – an Operate command has been received
- opOk – an Operate command has been accepted
- tOpOk – the time at which the output was activated
- operTimeout – Operator Timeout (CF) in milliseconds

Measured Value - MV

MV class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
measured attributes					
instMag	AnalogueValue	MX			O
mag	AnalogueValue	MX	dchg, dupd		M
range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
q	Quality	MX	qchg		M
t	TimeStamp	MX			M
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subMag	AnalogueValue	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
units	Unit	CF	dchg	see Annex A	O
db	INT32U	CF	dchg	0 … 100 000	O
zeroDb	INT32U	CF	dchg	0 … 100 000	O
sVC	ScaledValueConfig	CF	dchg		AC_SCAV
rangeC	RangeConfig	CF	dchg		GC_CON_range
smpRate	INT32U	CF	dchg		O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

instMag v.s. mag (edition 1)

mag	Deadbanded value. Shall be based on a dead band calculation from instMag as illustrated below. The value of mag shall be updated to the current value of instMag when the value has changed according the configuration parameter db.  NOTE 7 The figure above is an example. There may be other algorithms providing a comparable result; for example as an alternate solution, the dead band calculation may use the integral of the change of instMag. The algorithm used is a local issue. NOTE 8 This value mag is typically used to create reports for analogue values. Such a report sent "by exception" is not comparable to the transfer of sampled measured values as supported by the CDC SAV.

- Use mag in datasets to trigger a report when data changes
- Use instMag in datasets for reporting data without triggering a report

Measured Value - MV

MV class					
Data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
			measured attributes		
instMag	AnalogueValue	MX			O
mag	AnalogueValue	MX	dchg, dupd		M
range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
q	Quality	MX	qchg		M
t	TimeStamp	MX			M
			substitution and blocked		
subEna	BOOLEAN	SV			PICS_SUBST
subMag	AnalogueValue	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
			configuration, description and extension		
units	Unit	CF	dchg	see Annex A	O
db	INT32U	CF	dchg	0 … 100 000	O
zeroDb	INT32U	CF	dchg	0 … 100 000	O
sVC	ScaledValueConfig	CF	dchg		AC_SCAV
rangeC	RangeConfig	CF	dchg		GC_CON_range
smpRate	INT32U	CF	dchg		O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

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AnalogueValue

AnalogueValue Type Definition			
Attribute Name	**Attribute Type**	**Value/Value Range**	**M/O/C**
i	INT32	integer value	GC_1
f	FLOAT32	floating point value	GC_1

From IEC61850-7-3

GC_1 = At least one attribute must be present.

Range Configuration (RangeConfig)

	RangeConfig type definition			
	Attribute name	**Attribute type**	**Value/Value range**	**M/O/C**
	hhLim	AnalogueValue		M
	hLim	AnalogueValue		M
	lLim	AnalogueValue		M
	llLim	AnalogueValue		M
	min	AnalogueValue		M
	max	AnalogueValue		M
Edition 2	limDb	INT32U	0 … 100 000	O

min < llLim < lLim < hLim < hhLim < max

limDb – Limit deadband in units of .001% of full scale for hysteresis of range alarms

Sampled Values (SAV)

SAV class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
			measured attributes		
instMag	AnalogueValue	MX			M
q	Quality	MX	qchg		M
t	TimeStamp	MX			O
			configuration, description and extension		
units	Unit	CF	dchg	see Annex A	O
sVC	ScaledValueConfig	CF	dchg		AC_SCAV
min	AnalogueValue	CF	dchg		O
max	AnalogueValue	CF	dchg		O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Complex Measured Value (CMV)

	DataAttribute					
				measured attributes		
	instCVal	Vector	MX			O
	cVal	Vector	MX	dchg, dupd		M
	range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
Edition 2	rangeAng	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
	q	Quality	MX	qchg		M
	t	TimeStamp	MX			M
				substitution and blocked		
	subEna	BOOLEAN	SV			PICS_SUBST
	subCVal	Vector	SV			PICS_SUBST
	subQ	Quality	SV			PICS_SUBST
Edition 2	subID	VISIBLE STRING64	SV			PICS_SUBST
	blkEna	BOOLEAN	BL			O
				configuration, description and extension		
	units	Unit	CF	dchg	see Annex A	O
	db	INT32U	CF	dchg	0 … 100 000	O
	dbAng	INT32U	CF	dchg	0 … 100 000	O
	zeroDb	INT32U	CF	dchg	0 … 100 000	O
	rangeC	RangeConfig	CF	dchg		GC_CON_range
Edition 2	rangeAngC	RangeConfig	CF	dchg		GC_CON_rangeAng
	magSVC	ScaledValueConfig	CF	dchg		AC_SCAV
Edition 2	angSVC	ScaledValueConfig	CF	dchg		AC_SCAV
	angRef	ENUMERATED	CF	dchg	V | A | other | Synchrophasor	O
	smpRate	INT32U	CF	dchg		O
	d	VISIBLE STRING255	DC		Text	O
	dU	UNICODE STRING255	DC			O
	cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
	cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
	dataNs	VISIBLE STRING255	EX			AC_DLN_M

Vector and AnalogueValue

Vector Type Definition			From IEC61850-7-3
Attribute Name	**Attribute Type**	**Value/Value Range**	**M/O/C**
mag	AnalogueValue		M
ang	AnalogueValue		O

AnalogueValue Type Definition			From IEC61850-7-3
Attribute Name	**Attribute Type**	**Value/Value Range**	**M/O/C**
i	INT32	integer value	GC_1
f	FLOAT32	floating point value	GC_1

GC_1 = At least one attribute must be present.

WYE Connected Measurements (WYE)

WYE class					
Data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
SubDataObject					
phsA	CMV				GC_1
phsB	CMV				GC_1
phsC	CMV				GC_1
neut	CMV				GC_1
net	CMV				GC_1
res	CMV				GC_1
DataAttribute					
configuration, description and extension					
angRef	ENUMERATED	CF	dchg	Va | Vb | Vc | Aa | Ab | Ac | Vab | Vbc | Vca | Vother | Aother | Synchrophasor	O
phsToNeut (Edition 2)	BOOLEAN	CF	dchg	DEFAULT = FALSE	O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

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Delta Connected Measurements (DEL)

DEL class					
data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
SubDataObject					
phsAB	CMV				GC_1
phsBC	CMV				GC_1
phsCA	CMV				GC_1
DataAttribute					
configuration, description and extension					
angRef	ENUMERATED	CF	dchg	Va | Vb | Vc | Aa | Ab | Ac | Vab | Vbc | Vca | Vother | Aother | Synchrophasor	O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Analog Setting (ASG)

ASG class					
attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
setting					
setMag	AnalogueValue	SP	dchg		AC_NSG_M
setMag	AnalogueValue	SG, SE			AC_SG_M
configuration, description and extension					
units	Unit	CF	dchg	see Annex A	O
sVC	ScaledValueConfig	CF	dchg		AC_SCAV
minVal	AnalogueValue	CF	dchg		O
maxVal	AnalogueValue	CF	dchg		O
stepSize	AnalogueValue	CF	dchg	0 … (maxVal – minVal)	O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

- AC_NSG_M Mandatory if Setting Groups are NOT supported
- AC_SG_M Mandatory if Setting Groups are supported

Object Reference Syntax

The **ObjectReference** syntax shall be:

LDName/LNName[.Name[. ...]]

– The "/" shall separate the instance name of a logical device (**LDName**) from the name of an instance of a logical node (**LNName**).
– The "." shall separate the further names in the hierarchy.
– The "[.]" indicates an option.
– The "[. ...]" indicates further names of recursively nested definitions.
– The "(…)" shall indicate an array element
– The type is VISIBLESTRING129

Service Tracking CDCs

- Used in ACSI (IEC 61850-7-2) to provide the means to control and track control blocks and commands.
  - Replaces the object type descriptions of control blocks in Edition 1.
  - Mapping in IEC 61850-8-1 results in substantially similar objects and interactions.
- Based on a general Common Service Tracking (CST) CDC

Common Data Classes – Control Block Service Tracking

Name	Description
CTS	Common Service Tracking
BTS	Buffered Report Tracking Service
UTS	Unbuffered Report Tracking Service
LTS	Log Control Block Tracking Service
GTS	GOOSE Control Block Tracking Service
MTS	Multicast Sampled Value (9-2) Control Block Tracking Service
NTS	Unicast Sample Value (9-1) Control Block Tracking Service
SGCB	Setting Group Control Block Tracking Service

Service Tracking CDCs and Control Blocks

- The abstract definition of control blocks look substantially different in Edition 2 compared to Edition 1 with the addition of the service tracking CDCs.
- 8-1 Mapping results in the same basic control block structure although some have new parameters in Ed.2

IEC 61850 Tutorial
November 15, 2011

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Logical Nodes and Example Object Names

IEC61850 Logical Node Naming and Groups

Name	Description
Axxx	Automatic Control (5)
Cxxx	Supervisory Control (6).
Fxxx	Functional Blocks (9)
Gxxx	Generic Functions (5).
Ixxx	Interfacing/Archiving (6).
Kxxx	Mechanical and Non-Electrical Equipment (5)
Lxxx	System Logical Nodes (7).
Mxxx	Metering & Measurement (13).
Pxxx	Protection (31).
Qxxx	Power Quality Events (6)
Rxxx	Protection Related (11).
Sxxx	Sensors, Monitoring (11).
Txxx	Instrument Transformer (20).
Xxxx	Switchgear (2).
Yxxx	Power Transformer (4).
Zxxx	Other Equipment (15).
Wxxx	Wind (Set aside for other standards)
Oxxx	Solar (Set aside for other standards)
Hxxx	Hydropower (Set aside for other standards)
Nxxx	Power Plant (Set aside for other standards)
Bxxx	Battery (Set aside for other standards)
Fxxx	Fuel Cells (Set aside for other standards)

Logical Node Listing

- Partial Listing of IEC61850 logical nodes follows.
- We will look at a couple in detail
- Make a note of others you are interested in for a closer review

System Logical Nodes

Name	Description
LPHD	Physical Device
LLNO	Common Logical Node MANDATORY
LCCH	Physical Communications Channel Supervision
LGOS	GOOSE Subscription
LTIM	Time Management
LTMS	Time Master Supervision
LTRK	Service Tracking

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Automatic Control Logical Nodes

Name	Description
ANCR	Neutral Current Regulator
ARCO	Reactive Power Control
ARIS	Resistor Control
ATCC	Automatic Tap Changer controller
AVCO	Voltage Control

Supervisory Control Logical Nodes

Name	Description
CALH	Alarm Handling
CCGR	Cooling Group Control
CILO	Interlocking
CPOW	Point-on-wave switching
CSWI	Switch Controller
CSYN	Synchronizer Controller

Functional Block Logical Nodes

Name	Description
FCNT	Counter
FCSD	Curve Shape Description
FFIL	Generic Filter
FLIM	Control Function Output Limitation
FPID	PID Regulator
FRMP	Ramp Function
FSPT	Set-Point Control Function
FXOT	Action at Over Threshold
FXUT	Action at Under Threshold

Generic Function Logical Nodes

Name	Description
GAPC	Generic Automatic Process Control
GGIO	Generic Process I/O
GLOG	Generic Log
GSAL	Generic Security Application

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Interfacing and Archiving Logical Nodes

Name	Description
IARC	Archiving
IHMI	Human Machine Interface
ITCI	Telecontrol Interface
ITMI	Telemonitoring Interface
ISAF	Safety Alarm Function
ITPC	Teleprotection Communications Interface

Interfacing and Archiving Logical Nodes

Name	Description
KFAN	Fan
KFIL	Filter
KPMP	Pump
KTNK	Tank
KVLV	Valve Control

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Metering and Measurement Logical Nodes

Name	Description
~~**MDIF**~~	~~Differential measurements~~
MHAI	Harmonics or interharmonics
MHAN	Non phase related harmonics or interharmonics
MMTR	Metering
MMXN	Non phase related measurements
MMXU	Measurements
MSQI	Sequence and Imbalance
~~**MSTA**~~	~~Metering Statistics~~
MENV	Environmental Information
MFLK	Flicker Measurement
MHYD	Hydrological Information
MMDS	DC Measurement
MMET	Metrological Information

Protection Logical Nodes

Name	Description
PDIF	Differential
PDIR	Direction
PDIS	Distance
PDOP	Directional overpower
PDUP	Directional underpower
PFRC	Rate of change of frequency
PHAR	Harmonic restraint
PHIZ	Ground detector
PIOC	Instantaneous overcurrent
PMRI	Motor restart inhibition
PMSS	Motor starting time supervision
POPF	Over power factor
PPAM	Phase angle measuring

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Protection Logical Nodes (cont'd)

Name	Description
PSCH	Protection scheme
PSDE	Sensitive directional earth fault
PTEF	Transient earth fault
PTOC	Time over current
PTOF	Over frequency
PTOV	Over voltage
PTRC	Protection trip conditioning
PTTR	Thermal overload
PTUC	Under current
PTUV	Under voltage
PVOC	Voltage controlled time over current
PVPH	Volts per Hz
PZSU	Zero speed or under speed

Protection Logical Nodes (cont'd)

Name	Description
PRTR	Rotor Protection
PTHF	Thyristor Protection
PUPF	Underpower Factor Protection

Power Quality Events Logical Nodes

Name	Description
QFVR	Frequency Variation
QITR	Current Transient
QIUB	Current Unbalance Variation
QVTR	Voltage Transient
QVUB	Voltage Unbalance Variation
QVVR	Voltage Variation

Protection Related Logical Nodes

Name	Description
RDRE	Disturbance recorder function
RADR	Disturbance recorder channel analogue
RBDR	Disturbance recorder channel binary
RDRS	Disturbance record handling
RBRF	Breaker failure
RDIR	Directional element
RFLO	Fault locator
RPSB	Power swing detection/blocking
RREC	Auto reclosing
RSYN	Synchronism-check or synchronising
RMXU	Differential Measurements

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Sensors and Monitoring Logical Nodes

Name	Description
SARC	Monitoring and diagnostics for arcs
SIMG	Insulation medium supervision
SIML	Insulation medium supervision (liquid)
SPDC	Monitoring and diag. for partial discharges
SCBR	Circuit Breaker Supervision
SLTC	Tap Changer Supervision
SOPM	Supervision of Operating Mechanism
SPTR	Power Transformer Supervision
SSWI	Circuit Switch Supervision
STMP	Temperature Supervision
SVBR	Vibration Supervision

Instrument Transformer Logical Nodes

Name	Description
TCTR	Current transformer
TVTR	Voltage transformer
TANG	Angle
TAXD	Axial Displacement
TDST	Distance
TFLW	Liquid Flow
TFRQ	Frequency
TGSN	Generic Sensor
THUM	Humidity
TLVL	LMedia Level

Instrument Transformer Logical Nodes (cont'd)

Name	Description
TMGF	Magnetic Field
TMVM	Movement Sensor
TPOS	Position Indicator
TPRS	Pressure Sensor
TRTN	Rotation Transmitter
TSND	Sound Pressure Sensor
TTMP	Temperature Sensor
TTNS	Mechanical Tension/stress
TVBR	Virbration Sensor
TWPH	Water Acidity

Switchgear Logical Nodes

Name	Description
XCBR	Circuit Breaker
XSWI	Circuit Switch

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Power Transformer Logical Nodes

Name	Description
YEFN	Earth fault neutralizer
YLTC	Tap changer
YPSH	Power shunt
YPTR	Power transformer

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Other Power System Equipment Logical Nodes

Name	Description
ZAXN	Auxiliary network
ZBAT	Battery
ZBSH	Bushing
ZCAB	Power cable
ZCAP	Capacitor Bank
ZCON	Converter
ZGEN	Generator
ZGIL	Gas insulated line
ZLIN	Power overhead line
ZMOT	Motor
ZREA	Reactor
ZRRC	Rotating reactive component
ZSAR	Surge arrestor
ZTCF	Thyristor controlled frequency converter
ZTCR	Thyristor controlled reactive component
ZRES	Resistor
ZSCR	Semiconductor Controlled Rectifier
ZSMC	Synchronous Machine

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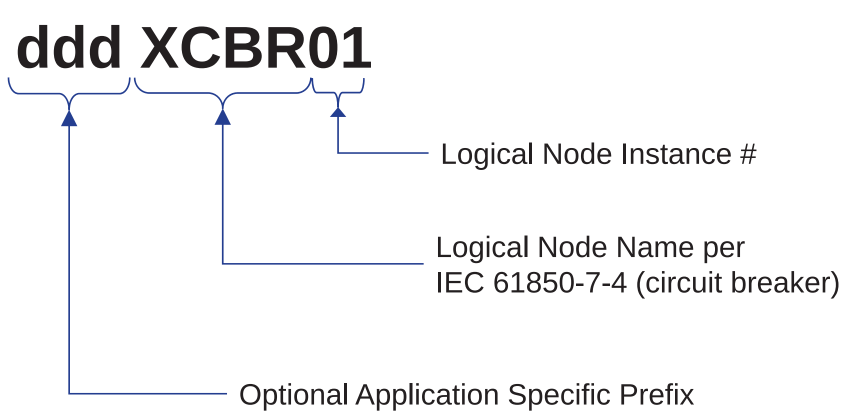
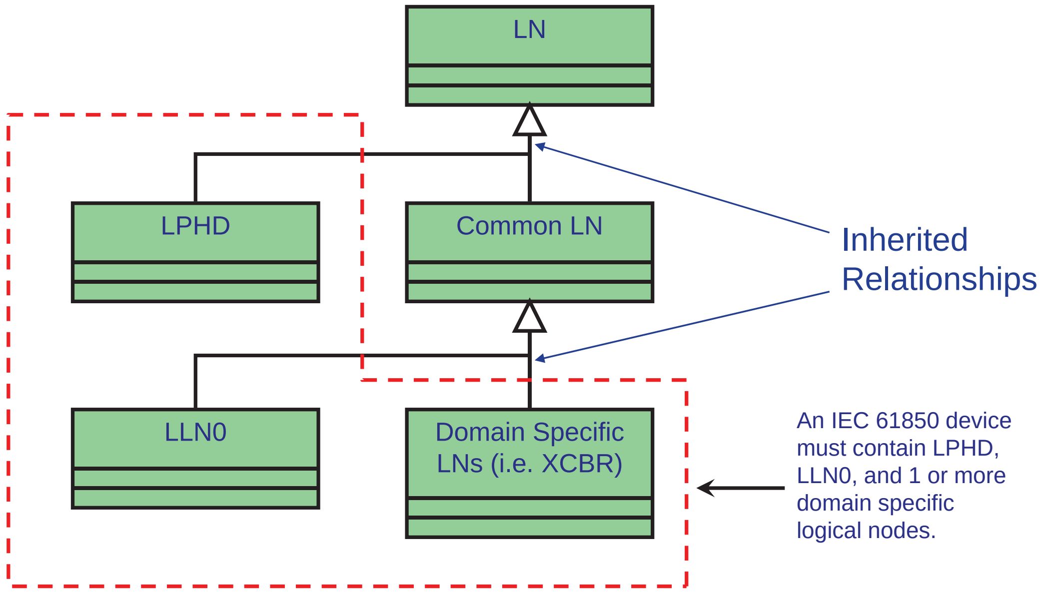
Logical Node Names

- Example for Breaker:



prefix digits + instance digits ≤ 7

Logical Node Classes



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Physical Device - LPHD

LPHD class				
Data object name	Common data class	Explanation	T	M/O/C
Data objects				
Status information				
PhyNam	DPL	Physical device name plate		M
PhyHealth	ENS	Physical device health		M
OutOv	SPS	Output communications buffer overflow		O
Proxy	SPS	Indicates if this LN is a proxy		M
InOv	SPS	Input communications buffer overflow		O
NumPwrUp	INS	Number of Power ups		O
WrmStr	INS	Number of Warm Starts		O
WacTrg	INS	Number of watchdog device resets detected		O
PwrUp	SPS	Power Up detected		O
PwrDn	SPS	Power Down detected		O
PwrSupAlm	SPS	External power supply alarm		O
Controls				
RsStat	SPC	Reset device statistics	T	O
Sim	SPC	Receive simulated GOOSE or simulated SV		O

Edition 2

Only LN that does not inherit Common LN properties. Inherits a name only.

Device Name Plate - DPL

DPL class					
Data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
configuration, description and extension					
vendor	VISIBLE STRING255	DC			M
hwRev	VISIBLE STRING255	DC			O
swRev	VISIBLE STRING255	DC			O
serNum	VISIBLE STRING255	DC			O
model	VISIBLE STRING255	DC			O
location	VISIBLE STRING255	DC			O
name	VISIBLE STRING64	DC			O
owner	VISIBLE STRING255	DC			O
ePSName	VISIBLE STRING255	DC			O
primeOper	VISIBLE STRING255	DC			O
secondOper	VISIBLE STRING255	DC			O
latitude	FLOAT32	DC			O
longitude	FLOAT32	DC			O
altitude	FLOAT32	DC			O
mrID	VISIBLE STRING255	DC			O
d	VISIBLE STRING255	DC			O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 2

Common Logical Node Class – Edition 1

Common Logical Node class				
Attribute Name	Attr. Type	Explanation	T	M/O
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Mandatory Logical Node Information (Shall be inherited by ALL LN but LPHD)				
Mod	INC	Mode		M
Beh	INS	Behaviour		M
Health	INS	Health		M
NamPlt	LPL	Name plate		M
Optional Logical Node Information				
Loc	SPS	Local operation		O
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
OpCntRs	INC	Operation counter resetable		O
OpCnt	INS	Operation counter		O
OpTmh	INS	Operation time		O

From IEC61850-7-4

ALL other logical nodes contain these attributes even though they are not listed in the other logical node description tables.

Common Logical Node Class – Edition 2 Changes

Common Logical Node class				
Attribute Name	**Attr. Type**	**Explanation**	**T**	**M/O**
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Mandatory Logical Node Information (Shall be inherited by ALL LN but LPHD)				
Mod	INC	Mode		M
Beh	INS	Behaviour		M
Health	INS	Health		M
NamPlt	LPL	Name plate		M
Optional Logical Node Information				
~~Loc~~	~~SPS~~	~~Local operation~~		~~O~~
~~EEHealth~~	~~INS~~	~~External equipment health~~		~~O~~
~~EEName~~	~~DPL~~	~~External equipment name plate~~		~~O~~
~~OpCntRs~~	~~INC~~	~~Operation counter resetable~~		~~O~~
~~OpCnt~~	~~INS~~	~~Operation counter~~		~~O~~
~~OpTmh~~	~~INS~~	~~Operation time~~		~~O~~

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Common Logical Node Class – Edition 2

Common LN class				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
Data objects				
Mandatory and conditional Logical Node Information (shall be inherited by ALL LN but LPHD)				
Mod	ENC	Mode		C1
Beh	ENS	Behavior		M
Health	ENS	Health		C1
NamPlt	LPL	Name plate		C1
Optional Logical Node Information				
InRef1	ORG	General input		O
BlkRef1	ORG	Blocking reference shows the receiving of dynamically blocking signal		O
Blk	SPS	Dynamically blocking of function described by the LN		O
CmdBlk	SPC	Blocking of control sequences and action triggers of controllable data objects		C2
GrRef	ORG	Reference to a higher level Logical Device		O

Common Logical Node Class – Edition 2 (cont'd)

Optional Logical Node Information (statistical calculation specific – refer to annex G)				
ClcExp	SPS	Calculation period expired	T	C3
ClcStr	SPC	Enables the calculation start at time operTm from the control model (if set) or immediately		O
ClcMth	ENG	Calculation Method of statistical data objects. Allowed values PRES_OR_UNKNOWN(default) | TRUE_RMS | PEAK_FUNDAMENTAL | RMS_FUNDAMENTAL | MIN | MAX | AVG | SDV |PREDICTION| RATE		C3
ClcMod	ENG	Calculation mode. Allowed values: TOTAL | PERIOD | SLIDING		C4
ClcIntvTyp	ENG	Calculation interval typ. Allowed values: MS | PER_CYCLE | CYCLE | DAY | WEEK | MONTH | YEAR | EXTERNAL		C4
ClcIntvPer	ING	In case ClcIntvTyp equals to MS, PER-CYCLE, CYCLE, DAY, WEEK, MONTH, YEAR, number of units to consider to calculate the calculation interval duration		C4
NumSubIntv	ING	The number of sub-intervals a calculation period interval duration contains		O
ClcRfTyp	ENG	Refreshment interval typ. Allowed values: MS, PER-CYCLE, CYCLE, DAY, WEEK, MONTH, YEAR, EXTERNAL		O
ClcRfPer	ING	In case ClcIntvTyp equals to MS, PER-CYCLE, CYCLE, DAY, WEEK, MONTH, YEAR, number of units to consider to calculate the refreshment interval duration		O
ClcSrc	ORG	Object Reference to Source logical node		C5
ClcNxTmms	ING	Remaining time up to the end of the current calculation interval – expressed in millisecond		O
InSyn	ORG	Object reference to the source of the external synchronization signal for the calculation interval		

Logical Node Name Plate - LPL

LPL class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
configuration, description and extension					
vendor	VISIBLE STRING255	DC			M
swRev	VISIBLE STRING255	DC			M
d	VISIBLE STRING255	DC			O
dU	UNICODE STRING255	DC			O
configRev	VISIBLE STRING255	DC			AC_LN0_M
paramRev	INT32	ST	dchg		O
valRev	INT32	ST	dchg		O
ldNs	VISIBLE STRING255	EX		shall be included in **LLN0** only; for example "IEC 61850-7-4:2003"	AC_LN0_EX
lnNs	VISIBLE STRING255	EX			AC_DLD_M
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Edition 2 (paramRev, valRev)

Mode and Behavior

Mode of LLN0 within that same logical device

Mode of the individual logical node

Behavior of the individual logical node is calculated

LNMode XXXX.Mod	LDMode LLN0.Mod	LNBeh (read only) XXXX.Beh	LNBeh Value
on	on	on	1
on	blocked	blocked	2
on	test	test	3
on	test-blocked	test-blocked	4
on	off	off	5
blocked	on	blocked	2
blocked	blocked	blocked	2
blocked	test	test-blocked	4
blocked	test-blocked	test-blocked	4
blocked	off	off	5
test	on	test	3
test	blocked	test-blocked	4
test	test	test	3
test	test-blocked	test-blocked	4
test	off	off	5
test-blocked	on	test-blocked	4
test-blocked	blocked	test-blocked	4
test-blocked	test	test-blocked	4
test-blocked	test-blocked	test-blocked	4
test-blocked	off	off	5
off	on	off	5
off	blocked	off	5
off	test	off	5
off	test-blocked	off	5
off	off	off	5

From IEC61850-7-4

Edition 2:
Blocked = On-Blocked

Health

Health	Value
OK (Green)	1
Warning (Yellow) minor problems but safe operation	2
Alarm (Red) severe problem no operation possible	3

Common Logical Node – LLN0

(Logical Node Zero)

	LLNO class				
	Data object name	Common data class	Explanation	T	M/O/C
	Data objects				
	Status information				
Edition 2	LocKey	SPS	Local operation for complete logical device		O
	LocSta	SPC	Switching authority at station level		O
	Loc	SPS	Local Control Behavior		O
	OpTmh	INS	Operation time		O
	Controls				
	Diag	SPC	Run Diagnostics		O
	LEDRs	SPC	LED reset	T	O
Edition 2	***Settings***				
	MltLev	SPG	Select mode of authority for local control (True – control from multiple levels above the selected one is allowed, False – no other control level above allowed)		O

The Mode (Mod) and Local/Remote status of this logical node affects all LNs in that Logical Device

GOOSE Subscription – LGOS – Edition 2

LGOS class				
Data object name	Common data class	Explanation	T	M/O/C
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22		
Data objects				
Status information				
SbsNdsCom	SPS	Subscription needs commissioning		O
SbsSt	SPS	Status of the subscription (True = active, False=not active)		O
SbsSim	SPS	Subscription wih simulation		O
LastStNum	INS	Last state number received		O
ConfRevNum	INS	Expected Configuration revision number		O
Settings				
GoCBRef	ORG	Reference to the subscribed GOOSE control block		O

Service Tracking – LTRK

LTRK class				
Data object name	Common data class	Explanation	T	M/O/C
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
Data objects				
SpcTrk	CTS	Control Service Tracking for Controllable Single Point		O
DpcTrk	CTS	Control Service Tracking for Controllable Double Point		O
IncTrk	CTS	Control Service Tracking for Controllable Integer		O
EncTrk	CTS	Control Service Tracking for Enumerated Controllable		O
ApcTrk	CTS	Control Service Tracking for Controllable Analog Set Point		O
BscTrk	CTS	Control Service Tracking for Binary controlled step position information		O
IscTrk	CTS	Control Service Tracking for Integer controlled step position information		O
BacTrk	CTS	Control Service Tracking for Binary controlled analog process value		O
UrcbTrk	UTS	Access Service Tracking for Unbuffered Report Control Block		O
BrcbTrk	BTS	Access Service Tracking for Buffered Report Control Block		O
LocbTrk	LTS	Access Service Tracking for Log Control Block		O
GocbTrk	GTS	Access Service Tracking for Goose Control Block		O
MsvcbTrk	MTS	Access Service Tracking for Multicast Sampled Values Control Block		O
UsvcbTrk	NTS	Access Service Tracking for Unicast Sampled Values Control Block		O
SgcbTrk	STS	Access Service Tracking for Settig Group Control Block		O

Logical Node Description – XCBR – Edition 2

	XCBR class				
	Data object name	Common data class	Explanation	T	M/O/C
	LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
	Data objects				
Edition 2	LocKey	SPS	Local or remote key (local means without substation automation communication, hardwired direct control)		O
Edition 2	LocSta	SPC	Switching authority at station level		O
	Loc	**SPS**	Local Control Behavior		M
	EEHealth	ENS	External equipment health		O
	EEName	DPL	External equipment name plate		O
	OpCnt	INS	Operation counter		M
	Controls				
	Pos	DPC	Switch position		M
	BlkOpn	SPC	Block opening		M
	BlkCls	SPC	Block closing		M
	ChaMotEna	SPC	Charger motor enabled		O
	Metered values				
	SumSwARs	BCR	Sum of Switched Amperes, resetable		O
	Status information				
	CBOpCap	INS	Circuit breaker operating capability		O
	POWCap	INS	Point On Wave switching capability		O
	MaxOpCap	INS	Circuit breaker operating capability when fully charged		O
Edition 2	Dsc	SPS	Discrepancy		O
Edition 2	***Settings***				
Edition 2	CBTmms	ING	Closing Time of breaker		O

Data Object Names — Common Data Class — Description — Mandatory/Optional/Conditional

Single Point Status (SPS) CDC

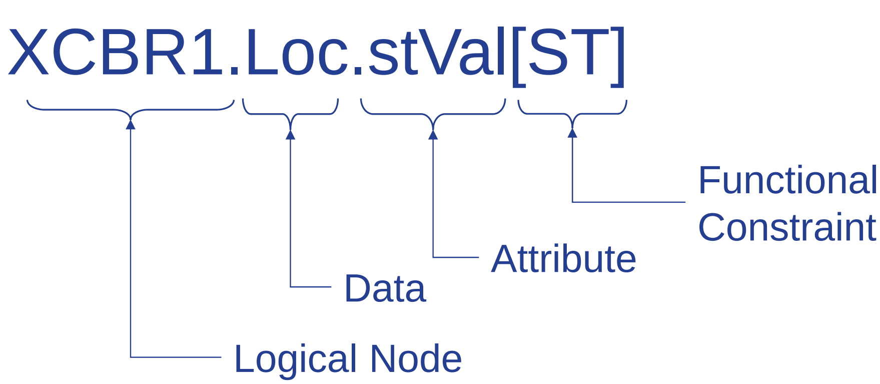
(e.g. loc)

SPS class					
Attribute Name	**Attribute Type**	**FC**	**TrgOp**	**Value/Value Range**	**M/O/C**
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute					From IEC61850-7-3
			status		
stVal	BOOLEAN	ST	dchg	TRUE | FALSE	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
			substitution		
subEna	BOOLEAN	SV			PICS_SUBST
subVal	BOOLEAN	SV		TRUE | FALSE	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
			configuration, description and extension		
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Data Attribute Names

Data Type of Attribute

7-1 Formatted Object Name



Same in Edition 1 or Edition 2

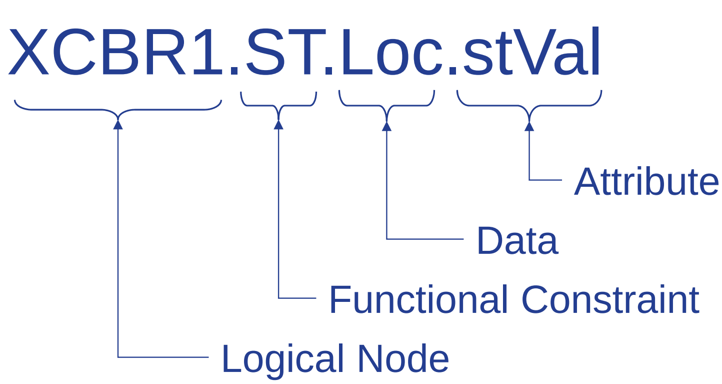
Mapping of Names via 8-1

- Section 8-1 maps the IEC61850 LN and Data Object Names to MMS (ISO9506)
- Functional Constraints must be after LN in order to support object hierarchy
- MMS allows only numbers, letters, “$”, and “_” in object names.
- Resulting MMS Object Name:

XCBR1STLoc$stVal

Same in Edition 1 or Edition 2

Alternate 8-1 Object Name for Local/Remote Attribute of XCBR1



Same in Edition 1 or Edition 2

Object Name Format Used in This Presentation

XCBR1.ST.Loc.stVal

or

XCBR1STLoc$stVal

Breaker Position

XCBR class				
Attribute Name	**Attr. Type**	**Explanation**	**T**	**M/O**
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data		From IEC61850-7-4		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
Loc	SPS	Local operation (local means without substation automation communication, hardwired direct control)		M
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
OpCnt	INS	Operation counter		M
Controls				
Pos	**DPC**	Switch position		M
BlkOpn	SPC	Block opening		M
BlkCls	SPC	Block closing		M
ChaMotEna	SPC	Charger motor enabled		O
Metered Values				
SumSwARs	BCR	Sum of Switched Amperes, resetable		O
Status Information				
CBOpCap	INS	Circuit breaker operating capability		M
POWCap	INS	Point On Wave switching capability		O
MaxOpCap	INS	Circuit breaker operating capability when fully charged		O

Breaker Position

	Data object name	Common data class	Explanation	T	M/O/C
	XCBR class				
	LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
	Data objects				
Edition 2	LocKey	SPS	Local or remote key (local means without substation automation communication, hardwired direct control)		O
Edition 2	LocSta	SPC	Switching authority at station level		O
	Loc	SPS	Local Control Behavior		M
	EEHealth	ENS	External equipment health		O
	EEName	DPL	External equipment name plate		O
	OpCnt	INS	Operation counter		M
	Controls				
	Pos	**DPC**	Switch position		M
	BlkOpn	SPC	Block opening		M
	BlkCls	SPC	Block closing		M
	ChaMotEna	SPC	Charger motor enabled		O
	Metered values				
	SumSwARs	BCR	Sum of Switched Amperes, resetable		O
	Status information				
	CBOpCap	INS	Circuit breaker operating capability		O
	POWCap	INS	Point On Wave switching capability		O
	MaxOpCap	INS	Circuit breaker operating capability when fully charged		O
Edition 2	Dsc	SPS	Discrepancy		O
Edition 2	***Settings***				
Edition 2	CBTmms	ING	Closing Time of breaker		O

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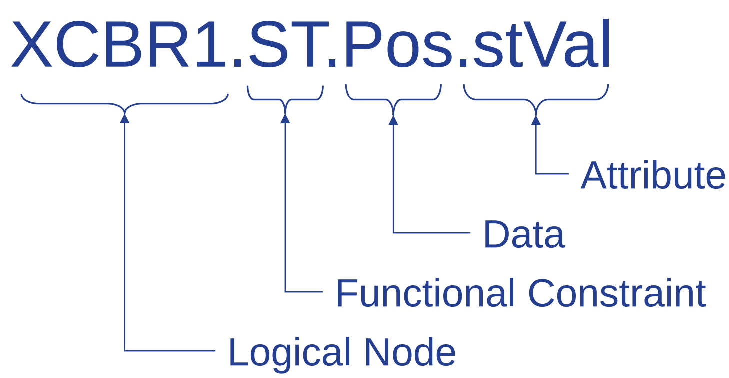
Breaker Position

Data attribute name	Type	FC	TrgOp	Value/Value range	M/O/C
DPC class					
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
		status and control mirror			
origin	Originator	ST			AC_CO_O
ctlNum	INT8U	ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		O
opRcvd	BOOLEAN	OR	dchg		O
opOk	BOOLEAN	OR	dchg		O
tOpOk	TimeStamp	OR			O
		substitution and blocked			
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
		configuration, description and extension			
pulseConfig	PulseConfig	CF	dchg		AC_CO_O
ctlModel	CtlModels	CF	dchg		M
sboTimeout	INT32U	CF	dchg		AC_CO_O
sboClass	SboClasses	CF	dchg		AC_CO_O
operTimeout	INT32U	CF	dchg		AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Object Name for Breaker Position Attribute of XCBR1



Measurement Unit (MMXU)

MMXU class				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
Data objects				
~~EEHealth~~	~~INS~~	~~External Equipment Health (external sensor)~~		~~O~~
Measured values				
TotW	MV	Total Active Power (Total P)		O
TotVAr	MV	Total Reactive Power (Total Q)		O
TotVA	MV	Total Apparent Power (Total S)		O
TotPF	MV	Average Power factor (Total PF)		O
Hz	MV	Frequency		O
PPV	DEL	Phase to phase voltages (VL1VL2, ...)		O
PNV	WYE	Phase to neutral voltage		O
PhV	WYE	Phase to ground voltages (VL1ER, ...)		O
A	WYE	Phase currents (IL1, IL2, IL3)		O
W	WYE	Phase active power (P)		O
VAr	WYE	Phase reactive power (Q)		O
VA	WYE	Phase apparent power (S)		O
PF	WYE	Phase power factor		O
Z	WYE	Phase Impedance		O

Edition 2 (PNV row)

MMXU (cont'd) Edition 2

AvAPhs	MV	Arithmetic average of the magnitude of current of the 3 phases. Average(Ia,Ib,Ic)		O
AvPPVPhs	MV	Arithmetic average of the magnitude of phase to phase voltage of the 3 phases. Average(PPVa, PPVb, PPVc)		O
AvPhVPhs	MV	Arithmetic average of the magnitude of phase to reference voltage of the 3 phases. Average(PhVa, PhVb, PhVc)		O
AvWPhs	MV	Arithmetic average of the magnitude of active power of the 3 phases. Average(Wa, Wb, Wc)		O
AvVAPhs	MV	Arithmetic average of the magnitude of apparent power of the 3 phases. Average(VAa, VAb, VAc)		O
AvVArPhs	MV	Arithmetic average of the magnitude of reactive power of the 3 phases. Average(VAra, VArb, VArc)		O
AvPFPhs	MV	Arithmetic average of the magnitude of power factor of the 3 phases. Average(PFa, PFb, PFc)		O
AvZPhs	MV	Arithmetic average of the magnitude of impedance of the 3 phases. Average(Za, Zb, Zc		O
MaxAPhs	MV	Maximum magnitude of current of the 3 phases. Max(Ia,Ib,Ic)		O
MaxPPVPhs	MV	Maximum magnitude of phase to phase voltage of the 3 phases. Max(PPVa, PPVb, PPVc)		O
MaxPhVPhs	MV	Maximum magnitude of phase to reference voltage of the 3 phases. Max(PhVa, PhVb, PhVc)		O
MaxWPhs	MV	Maximum magnitude of active power of the 3 phases. Max(Wa, Wb, Wc)		O
MaxVAPhs	MV	Maximum magnitude of apparent power of the 3 phases. Max(VAa, VAb, VAc)		O
MaxVArPhs	MV	Maximum magnitude of reactive power of the 3 phases. Max(VAra, VArb, VArc)		O
MaxPFPhs	MV	Maximum magnitude of power factor of the 3 phases. Max(PFa, PFb, PFc)		O

MMXU (cont'd) Edition 2

MaxZPhs	MV	Maximum magnitude of impedance of the 3 phases. Max(Za, Zb, Zc)		O
MinAPhs	MV	Minimum magnitude of current of the 3 phases. Min(Ia,Ib,Ic)		O
MinPPVPhs	MV	Minimum magnitude of phase to phase voltage of the 3 phases. Min(PPVa, PPVb, PPVc)		O
MinPhVPhs	MV	Minimum magnitude of phase to reference voltage of the 3 phases. Min(PhVa, PhVb, PhVc)		O
MinWPhs	MV	Minimum magnitude of active power of the 3 phases. Min(Wa, Wb, Wc)		O
MinVAPhs	MV	Minimum magnitude of apparent power of the 3 phases. Min(VAra, VArb, VArc)		O
MinVArPhs	MV	Minimum magnitude of reactive power of the 3 phases. Min(VAra, VArb, VArc)		O
MinPFPhs	MV	Minimum magnitude of power factor of the 3 phases. Min(PFa, PFb, PFc)		O
MinZPhs	MV	Minimum magnitude of impedance of the 3 phases. Min(Za, Zb, Zc)		O
Settings				
ClcTotVA	ENG	Calculation method used for total apparent power (TotVA) (VECTOR | ARITHMETIC)		O
PFSign	ENG	Sign convention for VAr and Power Factor (PF) (ActivePower | LEAD/LAG)		O

WYE Measurements

	WYE class					
	Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
	DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
	SubDataObject					
	phsA	CMV				GC_1
	phsB	CMV				GC_1
	phsC	CMV				GC_1
	neut	CMV				GC_1
	net	CMV				GC_1
	res	CMV				GC_1
	DataAttribute					
	configuration, description and extension					
	angRef	ENUMERATED	CF	dchg	Va | Vb | Vc | Aa | Ab | Ac | Vab | Vbc | Vca | Vother | Aother | Synchrophasor	O
Edition 2	phsToNeut	BOOLEAN	CF	dchg	DEFAULT = FALSE	O
	d	VISIBLE STRING255	DC		Text	O
	dU	UNICODE STRING255	DC			O
	cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
	cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
	dataNs	VISIBLE STRING255	EX			AC_DLN_M

Complex Measured Value

	CMV class					
	Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
	DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
	DataAttribute					
	measured attributes					
	instCVal	Vector	MX			O
	cVal	Vector	MX	dchg, dupd		M
	range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
	rangeAng	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
	q	Quality	MX	qchg		M
	t	TimeStamp	MX			M
	substitution and blocked					
	subEna	BOOLEAN	SV			PICS_SUBST
	subCVal	Vector	SV			PICS_SUBST
	subQ	Quality	SV			PICS_SUBST
	subID	VISIBLE STRING64	SV			PICS_SUBST
Edition 2	blkEna	BOOLEAN	BL			O
	configuration, description and extension					
	units	Unit	CF	dchg	see Annex A	O
	db	INT32U	CF	dchg	0 ... 100 000	O
	dbAng	INT32U	CF	dchg	0 ... 100 000	O
	zeroDb	INT32U	CF	dchg	0 ... 100 000	O
	rangeC	RangeConfig	CF	dchg		GC_CON_range
Edition 2	rangeAngC	RangeConfig	CF	dchg		GC_CON_rangeAng
	magSVC	ScaledValueConfig	CF	dchg		AC_SCAV
Edition 2	angSVC	ScaledValueConfig	CF	dchg		AC_SCAV
	angRef	ENUMERATED	CF	dchg	V | A | other ¦ Synchrophasor	O
	smpRate	INT32U	CF	dchg		O
	d	VISIBLE STRING255	DC		Text	O
	dU	UNICODE STRING255	DC			O
	cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
	cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
	dataNs	VISIBLE STRING255	EX			AC_DLN_M

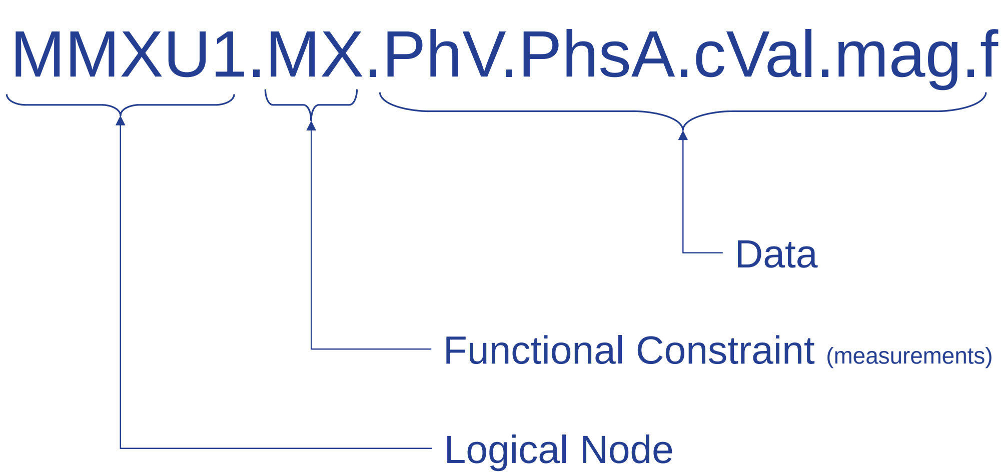
Vector

Vector type definition			
Attribute name	**Attribute type**	**Value / Value range**	**M / O / C**
mag	AnalogueValue		M
ang	AnalogueValue	–180 < n ≤ +180	AC_CLC_O

Edition 2

AnalogueValue type definition			
Attribute name	**Attribute type**	**Value / Value range**	**M / O / C**
i	INT32	integer value	GC_1
f	FLOAT32	floating point value	GC_1

Object Name for Phase A to Ground Voltage



Same in Ed. 1 and Ed. 2

Other Logical Node Standards

- IEC 61850-7-410 contains LN descriptions for hydro power (water)
- IEC 61850-7-420 contains LN descriptions for distributed energy resource (DER) applications (a.k.a. distributed generation)
- IEC 61400-25 contains LN descriptions for wind power applications.
- Some IEC 61850 devices have some proprietary LN definitions.

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Wind Turbine Generator (WTUR)

WTUR class			
Attribute Name	**Attr. Type**	**Explanation**	**M/O**
		LN shall inherit all Mandatory Data from Wind Power Plant Common Logical Node Class (see 6.1.1)	M
Data			
Common information			
AvlTmRs	TMS	Turbine availability time (vendor-specific)	O
OpTmRs	TMS	Operation time (vendor-specific)	O
StrCnt	CTE	Number of turbine starts (vendor-specific)	O
StopCnt	CTE	Number of turbine stops (vendor-specific)	O
TotWh	CTE	Total (net) active energy production	M
TotVArh	CTE	Total (net) reactive energy production	O
DmdWh	BCR	Active (real) energy demand (default demand direction: energy flow from a substation busbar away and towards the wind turbine)	O
DmdVArh	BCR	Reactive energy demand (default demand direction: energy flow from a substation busbar away and towards the wind turbine)	O
SupWh	BCR	Active (real) energy supply (default supply direction: energy flow from the wind turbine and towards a substation busbar)	O
SupVArh	BCR	Reactive energy supply (default supply direction: energy flow from the wind turbine and towards a substation busbar)	O
Status information			
TurSt	STV	Turbine status	M
Analogue information			
W	MV	Active power generation	M
VAr	MV	Reactive power generation	O
Control information			
SetTurOp	CMD	Wind turbine operation command	M
VArOvW	CMD	Windturbine reactive priority over active command	O
VArRefPri	CMD	Windturbine reactive setpoint priority command	O
DmdW	SPV	Turbine active power generation setpoint	O
DmdVAr	SPV	Turbine reactive power generation setpoint	O
DmdPF	SPV	Turbine power factor setpoint	O

Questions - Discussion

IEC 61850 users group **IEC 61850 Tutorial**

November 15, 2011

UCA International Users Group

UCAIug Summit Meeting
Austin, TX

Abstract Communications Service Interface

ACSI

ACSI
Abstract Communications Service Interface

- Defines a set of Objects
- Defines a set of Services to manipulate and access those objects
- Defines a base set of data types for describing objects

Ed. 1 ACSI Objects and MMS Mapping

ACSI Object Class	MMS Object
SERVER class	Virtual Manufacturing Device (VMD)
LOGICAL DEVICE class	Domain
LOGICAL NODE class	Named Variable
DATA class	Named Variable
DATA-SET class	Named Variable List
SETTING-GROUP-CONTROL-BLOCK class	Named Variable
REPORT-CONTROL-BLOCK class	Named Variable
LOG class	Journal
LOG-CONTROL-BLOCK class	Named Variable
GOOSE-CONTROL-BLOCK class	Named Variable
GSSE-CONTROL-BLOCK class	Named Variable
CONTROL class	Named Variable
Files	Files

ACSI Services

Enable Self Describing Devices

ACSI Services	MMS Services
LogicalDeviceDirectory	GetNameList
GetAllDataValues	Read
GetDataValues	Read
SetDataValues	Write
GetDataDirectory	GetVariableAccessAttributes
GetDataDefinition	GetVariableAccessAttributes
GetDataSetValues	Read
SetDataSetValues	Write
CreateDataSet	CreateNamedVariableList
DeleteDataSet	DeleteNamedVariableList
GetDataSetDirectory	GetVariableAccessAttributes
Report (Buffered and Unbuffered)	InformationReport
GetBRCBValues/GetURCBValues	Read
SetBRCBValues/SetURCBValues	Write
GetLCBValues	Read
SetLCBValues	Write
QueryLogByTime	ReadJournal
QueryLogAfter	ReadJournal
GetLogStatusValues	GetJournalStatus
Select	Read/Write
SelectWithValue	Read/Write
Cancel	Write
Operate	Write
Command-Termination	Write

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SERVER Object and Services

SERVER class		From IEC61850-7-2
Attribute name	**Attribute type**	**Value/value range/explanation**
ServiceAccessPoint [1..n]	(*)	(*) Type is SCSM specific
LogicalDevice [1..n]	LOGICAL-DEVICE	
File [0..n]	FILE	
TPAppAssociation [0..n]	TWO-PARTY-APPLICATION-ASSOCIATION	
MCAppAssociation [0..n]	MULTICAST-APPLICATION-ASSOCIATION	
Services GetServerDirectory		

- Obtain a list of:
  - Logical Devices
    - MMS GetNameList service, Object Class = domain
  - Files
    - MMS FileDirectory service

LOGICAL DEVICE Object and Services

LOGICAL-DEVICE class		From IEC61850-7-2
Attribute name	**Attribute type**	**Value/value range/explanation**
LDName	ObjectName	Instance name of an instance of LOGICAL-DEVICE
LDRef	ObjectReference	Path-name of an instance of LOGICAL-DEVICE
LogicalNode [3..n]	LOGICAL-NODE	IEC 61850-7-4 specifies specialized classes of LOGICAL-NODE
Services GetLogicalDeviceDirectory		

- Obtain a list of Logical Nodes in a Logical Device:
  - MMS GetNameList where Object Class = Variable and Domain = Logical Device name

LOGICAL NODE Class

LOGICAL-NODE class		From IEC61850-7-2
Attribute name	**Attribute type**	**Explanation**
LNName	ObjectName	Instance name of an instance of LOGICAL-NODE
LNRef	ObjectReference	Path-name of an instance of LOGICAL-NODE
Data [1..n]	DATA	
DataSet [0..n]	DATA-SET	
BufferedReportControlBlock [0..n]	BRCB	
UnbufferedReportControlBlock [0..n]	URCB	
LogControlBlock [0..n]	LCB	
IF compatible LN class defined in IEC 61850-7-4 equals LLN0		
SettingGroupControlBlock [0..1]	SGCB	
Log [0..1]	LOG	
GOOSEControlBlock [0..n]	GoCB	
GSSEControlBlock [0..n]	GsCB	
MulticastSampledValueControlBlock [0..n]	MSVCB	
UnicastSampledValueControlBlock [0..n]	USVCB	
Services GetLogicalNodeDirectory GetAllDataValues		

LOGICAL NODE Services

From IEC61850-7-2

Service	Description
GetLogicalNodeDirectory	Retrieve ObjectReferences of a specific ACSI class contained in the **LOGICAL-NODE**
GetAllDataValues	Retrieve all **DataAttribute** values of all **DATA** contained in the **LOGICAL-NODE**

- GetLogicalNodeDirectory
  - MMS GetNameList where
    - ObjectClass = Variable Name, NamedVariableList, and Journal
    - ObjectScope = Logical Device Name
    - (Can be simplified)
- GetAllDataValues
  - MMS Read where Variable Name = Logical Node Name

ACSI Services for DATA

From IEC61850-7-2

Service	Description
GetDataValues	Retrieve values of **DATA** contained in the **LOGICAL-NODE**
SetDataValues	Write values of **DATA** contained in the **LOGICAL-NODE**
GetDataDirectory	Retrieve ObjectReferences of all **DataAttributes** contained in the **DATA**
GetDataDefinition	Retrieve definitions of all **DataAttributes** contained in the **DATA**

- GetDataValues
  - MMS Read where Variable Name = name of DATA Object
- SetDataValues
  - MMS Write where Variable Name = name of DATA Object
- GetDataDirectory and GetDataDefinition
  - MMS GetVariableAccessAttributes

ACSI Service Mapping using MMS

- GetLogicalNodeDirectory:
  - GetNameList of variables in Logical Device domain (variables defined under MMXU1)
- GetAllDataValues
  - Read MMXU1

ACSI Service Mapping using MMS

- GetDataDirectory maps to
  - **GetVariableAccessAttributes** of:
    - MMXU1MX PhV
    - MMXU1CF PhV
    - MMXU1DC PhV
    - MMXU1EX PhV
    - MMXU1SV PhV
  - To obtain list of data defined within PhV (cVal or instCVal, range, q, t, subEna, etc.)
- GetDataDefinition maps to
  - **GetVariableAccessAttributes** of:
    - MMXU1MX PhV$PhsA – PhsB – PhsC
    - MMXU1CF PhV$PhsA – PhsB – PhsC
    - MMXU1DC PhV$ PhsA – PhsB – PhsC
    - MMXU1EX PhV$ PhsA – PhsB – PhsC
    - MMXU1SV PhV$ PhsA – PhsB – PhsC
  - To obtain list and type of data contained within PhV (cValmagf, cValangf, etc.)

IEC61850 Client Simplification

- Rather than executing multiple GetVariableAccessAttribute requests for each and every element of MMXU:
  - A smart IEC 61850 client will perform a GetVariableAccessAttributes on the MMXU1 object and derive all the LOGICAL NODE, DATA, and attribute information from a single response.

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DATA-SET

- Named object consisting of a set of DATA
- Maps to an MMS Named Variable List in IEC61850-8-1
- Typically used in Reporting and for Sample Measured Values

DATA-SET Object and Services

DATA-SET class		From IEC61850-7-2
Attribute name	**Attribute type**	**Value/value range/explanation**
DSName	ObjectName	Instance name of an instance of DATA-SET
DSRef	ObjectReference	Path-name of an instance of DATA-SET
DSMemberRef [1..n]	(*)	(*) Functionally constrained data (**FCD**) or functionally constrained data attribute (**FCDA**)
Services GetDataSetValues SetDataSetValues CreateDataSet DeleteDataSet GetDataSetDirectory		

- GetDataSetValues = Read
- SetDataSetValues = Write
- CreateDataSet = DefineNamedVariableList
- DeleteDataSet = DeleteNamedVariableList
- GetDataSetDirectory = GetNamedVariableListAttributes

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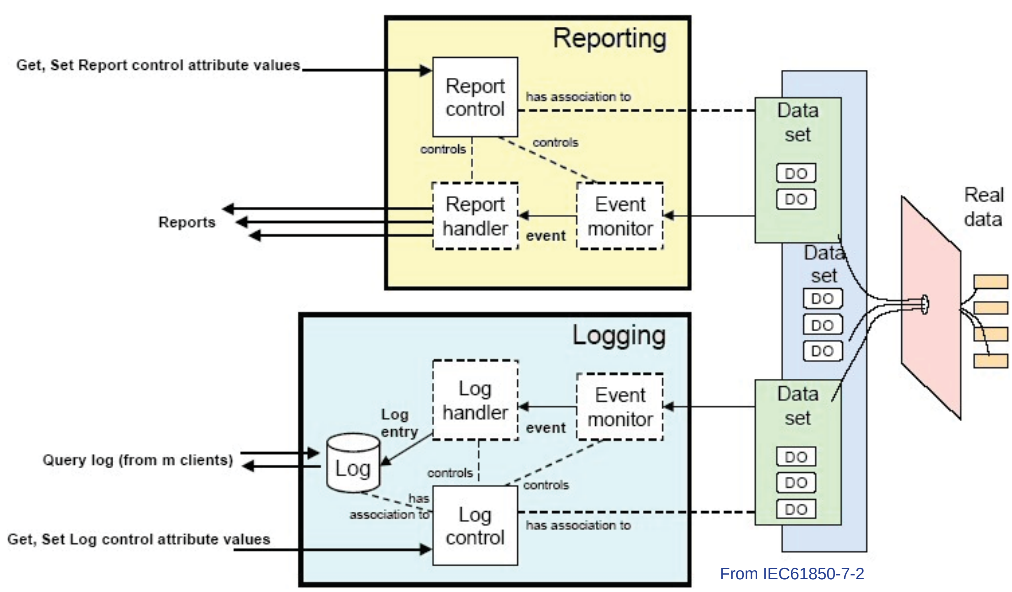
Report Model

Reporting

- Unbuffered Reporting allows clients to receive data from the server without polling.
  - If network connection (association) between client and server is lost, data is lost.
  - Equivalent to UCA2.0 Reporting
- Buffered reporting enables the server to retain data if associations are lost enabling the client to retrieve ALL data.
- 8-1 SCSM: Reports are sent using MMS InformationReport

Report-Log Model



From IEC61850-7-2

Report Control Block Attributes

Attribute Name	Description
RptID	Name assigned to this URCB
RptEna	= 1 Reports enabled, = 0 Reports disabled
Resv	= 1 In-use by client, =0 Available **(unbuffered only)**
DatSet	Name of the DATA-SET reference
ConfRev	Configuration Revision Number (can track Data Set changes)
OptFlds	Optional Fields to Include in the Report
sequence-number	Include the sequence number
report-time-stamp	Include a report time stamp (even if DATA is time stamped)
reason-for-inclusion	The reason the report was sent (dchg, qchg, etc.)
data-set-name	Include the DATA-SET name in the report
data-reference	Include the names of the DATA elements in the report
buffer-overflow	Include buffer status in report **(buffered only)**
entry-ID	Include the entry ID in the report **(buffered only)**
conf-revision	Include the current value of the ConfRev in the report
BufTim	Buffer Time (the fastest that reports will be sent)
SqNum	Sequence Number
TrgOp	Trigger Conditions
data-change	Send report on data change exceeding deadband
data-update	Send report if data is updated even if it didn't change
	Send report on change in quality
integrity	Send report on integrity period expiration
general-interrogation	Send report when requested
IntPd	Integrity Period
GI	General Interrogation
PurgeBuf	Purge the report buffer **(buffered only)**
EntryID	Start reporting from a specific entry in the buffer **(buffered only)**
TimeOfEntry	Start reporting from a specific entry time **(buffered only)**
ResvTms	Reservation Timer **(buffered only)** - **OPTIONAL** EDITION 2
Owner	Client ID of RCB owner - **OPTIONAL** EDITION 2

Report Services

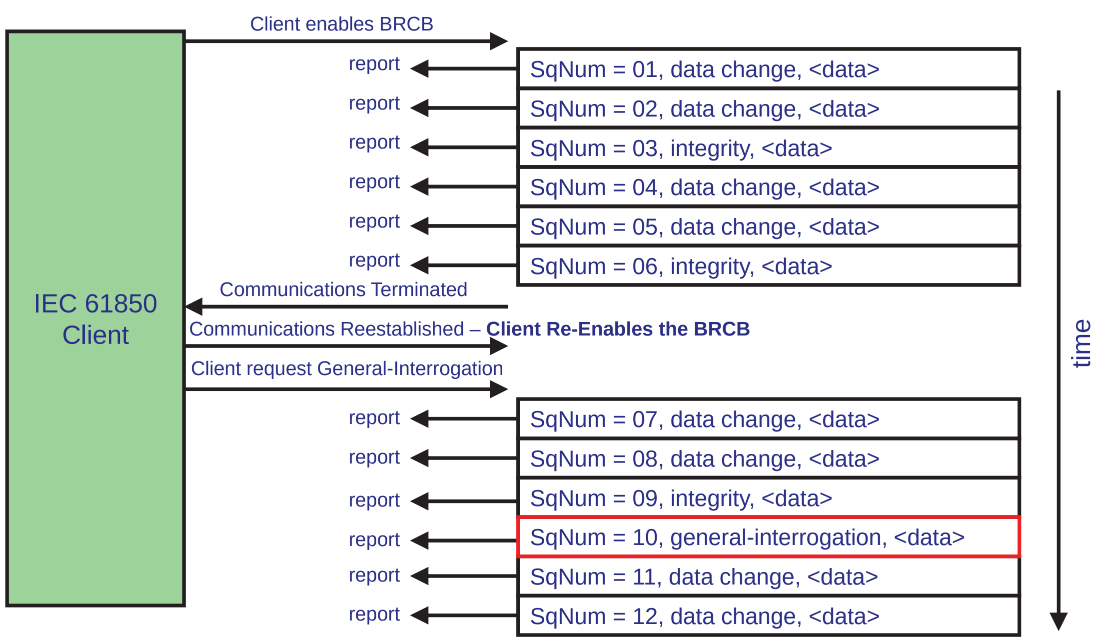
Service	Description (From IEC61850-7-2)
Report	Send a report
GetBRCBValues	Read an attribute of a **BRCB**
SetBRCBValues	Write an attribute of a **BRCB**
GetURCBValues	Read an attribute of an instance of **URCB**
SetURCBValues	Write an attribute of an instance of **URCB**

- Report = MMS Information Report
- GetBRCBValues or GetURCBValues
  - MMS Read
- SetBRCBValues or SetURBCValues
  - MMS Write

Example Reporting Sequence

1. Find BRCB where Resv = 0 and Write Resv = 1
2. Write OptFlds, BufTim, TrgOp, IntgPd (DataSet, etc.) to desired values:
    1. MMXU1BRbrcbMX$OptFlds = 011110001000000 (include: Sequence #, report time stamp, reason for inclusion, data set name, and configuration revision)
    2. MMXU1BRbrcbMX$BufTim = 500 (500 milliseconds)
    3. MMXU1BRbrcbMX$TrgOp = 01101000 (data, quality, and integrity only)
    4. MMXU1BRbrcbMX$IntgPd = 60000 (1 minute)
3. Enable Report
    1. MMXU1BRbrcbMX$RptEna = 1
4. Receive Reports

Buffered Reporting with GI Example



SqNum = 10 flags when the GI was issued by the client to identify data that was reported while disconnected.

Using Modeling to Control Reports

- Requirements:
  - Desire to receive average readings of current measurements on all 3 phases of a feeder and the actual voltage measurement on one phase every 10 minutes.
  - Any under or over voltage or current conditions should be reported immediately.
- Use MSTA for average current measurements
- Use MMXU for actual voltage measurement and range alarms
- Example using Edition 1. Use statistical measurements in MMXU for Edition 2.

Metering Statistics (MSTA)

From IEC61850-7-4

MSTA class				
Attribute Name	**Attr. Type**	**Explanation**	**T**	**M/O**
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
EEHealth	INS	External equipment health (external sensor)		O
EEName	DPL	External equipment name plate		O
Metered Values				
AvAmps	MV	Average current		O
MaxAmps	MV	Maximum current		O
MinAmps	MV	Minimum current		O
AvVolts	MV	Average voltage		O
MaxVolts	MV	Maximum voltage		O
MinVolts	MV	Minimum voltage		O
AvVA	MV	Average apparent power		O
MaxVA	MV	Maximum apparent power		O
MinVA	MV	Minimum apparent power		O
AvW	MV	Average real power		O
MaxW	MV	Maximum real power		O
MinW	MV	Minimum real power		O
AvVAr	MV	Average reactive power		O
MaxVAr	MV	Maximum reactive power		O
MinVAr	MV	Minimum reactive power		O
Controls				
EvStr	SPC	Start of evaluation interval		O
Settings				
EvTmms	ASG	Evaluation time (time window) for averages, etc.		O

Measured Value - MV

MV class					
Attribute Name	Attribute Type	FC	TrgOp	Value/Value Range	M/O/C
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute				From IEC61850-7-3	
			measured attributes		
instMag	AnalogueValue	MX			O
mag	AnalogueValue	MX	dchg		M
range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low|...	O
q	Quality	MX	qchg		M
t	TimeStamp	MX			M
			substitution		
subEna	BOOLEAN	SV			PICS_SUBST
subMag	AnalogueValue	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
		configuration, description and extension			
units	Unit	CF		see Annex A	O
db	INT32U	CF		0 ... 100 000	O
zeroDb	INT32U	CF		0 ... 100 000	O
sVC	ScaledValueConfig	CF			AC_SCAV
rangeC	RangeConfig	CF			GC_CON
smpRate	INT32U	CF			O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Measurement Unit (MMXU)

MMXU class				
Attribute Name	Attr. Type	Explanation	T	M/O
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data		From IEC61850-7-4		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
EEHealth	INS	External equipment health (external sensor)		O
Measured values				
TotW	MV	Total Active Power (Total P)		O
TotVAr	MV	Total Reactive Power (Total Q)		O
TotVA	MV	Total Apparent Power (Total S)		O
TotPF	MV	Average Power factor (Total PF)		O
Hz	MV	Frequency		O
PPV	DEL	Phase to phase voltages (VL1VL2, ...)		O
PhV	WYE	Phase to ground voltages (VL1ER, ...)		O
A	WYE	Phase currents (IL1, IL2, IL3)		O
W	WYE	Phase active power (P)		O
VAr	WYE	Phase reactive power (Q)		O
VA	WYE	Phase apparent power (S)		O
PF	WYE	Phase power factor		O
Z	WYE	Phase Impedance		O

WYE Measurements

WYE class					
Attribute Name	**Attribute Type**	**FC**	**TrgOp**	**Value/Value Range**	**M/O/C**
DataName	Inherited from Data Class (see IEC 61850-7-2)				
Data				From IEC61850-7-3	
phsA	CMV				GC_1
phsB	CMV				GC_1
phsC	CMV				GC_1
neut	CMV				GC_1
net	CMV				GC_1
res	CMV				GC_1
DataAttribute					
				configuration, description and extension	
angRef	ENUMERATED	CF		Va | Vb | Vc | Aa | Ab | Ac | Vab | Vbc | Vca | Vother | Aother	O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Complex Measured Value (CMV)

CMV class					
Attribute Name	**Attribute Type**	**FC**	**TrgOp**	**Value/Value Range**	**M/O/C**
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute				From IEC61850-7-3	
				measured attributes	
instCVal	Vector	MX			O
cVal	Vector	MX	dchg		M
range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low|…	O
q	Quality	MX	qchg		M
t	TimeStamp	MX			M
				substitution	
subEna	BOOLEAN	SV			PICS_SUBST
subCVal	Vector	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
				configuration, description and extension	
units	Unit	CF		see Annex A	O
db	INT32U	CF		0 … 100 000	O
zeroDb	INT32U	CF		0 … 100 000	O
rangeC	RangeConfig	CF			GC_CON
magSVC	ScaledValueConfig	CF			AC_SCAV
angSVC	ScaledValueConfig	CF			AC_SCAV
angRef	ENUMERATED	CF		V | A | other …	O
smpRate	INT32U	CF			O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Solution

- Define a Dataset containing:
  - phsAMSTA1.MX.AvAmps.instMag.f
  - phsBMSTA2.MX.AvAmps.instMag.f
  - phsCMSTA3.MX.AvAmps.instMag.f
  - MMXU1.MX.PhV.phsA.instCVal.mag.f
  - MMXU1.MX.A.phsA.range
  - MMXU1.MX.A.phsB.range
  - MMXU1.MX.A.phsC.range
  - MMXU1.MX.PhV.phsA.range
  - MMXU1.MX.PhV.phsB.range
  - MMXU1.MX.PhV.phsC.range

None of these values have TrgOp = dchg so they will not trigger reports when their value changes. Their values will only be sent in Integrity reports or if a range alarm occurs.

A change in ANY of these values will cause a immediate report to be sent AFTER the BuffTim expires as long as the RCB is enabled and TrgOp = dchg is set.

- Assign this dataset to a report control block with:
  - Integrity = 10 minutes
  - TrgOp = data-change and integrity
- Enable the report

Questions - Discussion

Controls

Control Model Objects

- Enables control of ACSI Objects:
  - Controllable Single Point (SPC)
  - Controllable Double Point (DPC)
  - Controllable Integer Status (INC)
  - Binary Controlled Step Position (BSC)
  - Integer Controlled Step Position (ISC)
  - Controllable Analog Set Point (APC)

Control Model Services

- Services available for controlling objects:
  - Select (Sel)
  - SelectWithValue (SelVal)
  - Cancel
  - Operate (Oper)
  - TimeActivatedOperate (TimOper)
  - Command Termination

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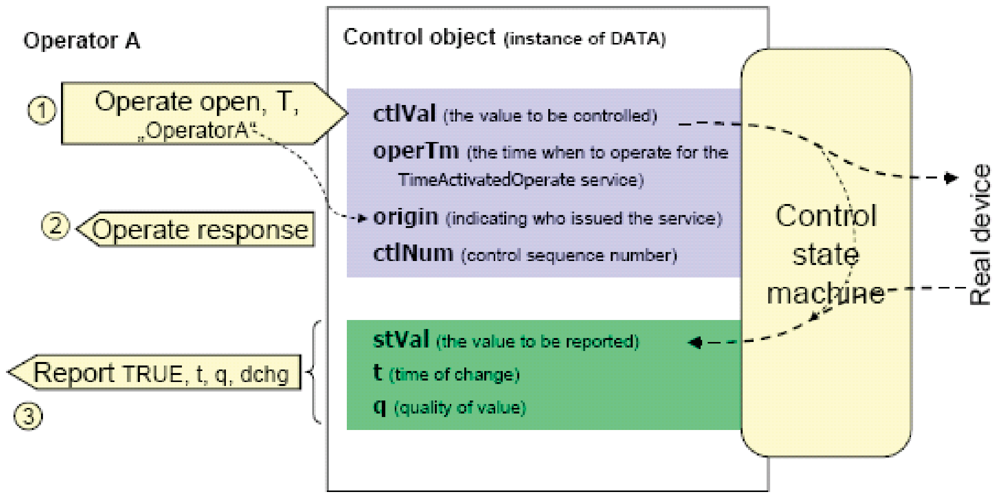
Control Model (ctlModel)

- 0: Status only. No control allowed.
- 1: Direct control with normal security (**direct-operate**)
- 2: SBO control with normal security (**operate-once** or **operate-many**)
- 3: Direct control with enhanced security (**direct-operate**)
- 4: SBO control with enhanced security (**operate-once** or **operate-many**)

General Control Model



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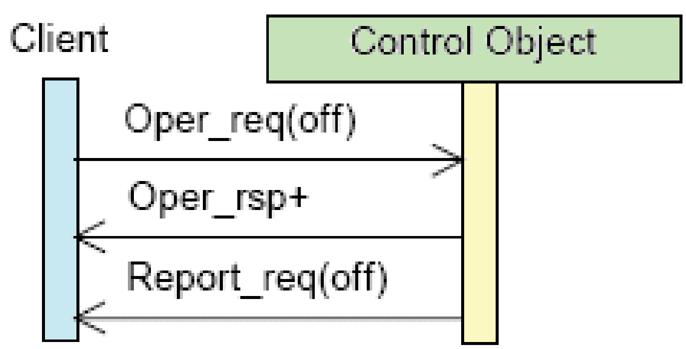
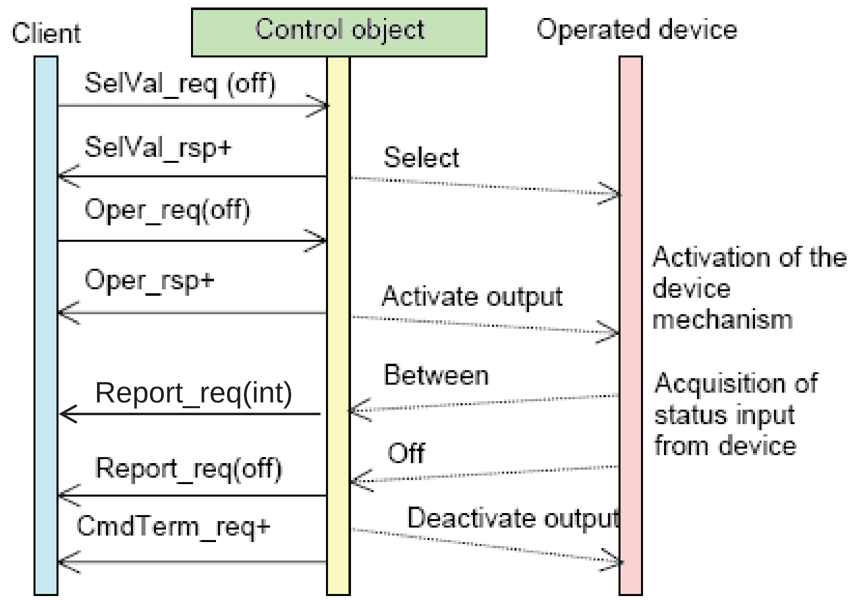
Direct Control with Normal Security



SBO Control with Enhanced Security



Mapping Controls to MMS

- IEC61850-8-1 adds attributes to control objects in Appendix E:
  - SBO – for Select operations
  - SBOw – for SelectWithValue operations
  - Oper – for operate, cancel, and commandtermination services
- Replaces CDC objects with CO functional constraint

SBO Structure for DPC

DPC class					
Attribute name	Attribute type	FC	TrgOp	Value/value range	M/O/C
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute					
control					
SBO	VISIBLE STRING65	CO			AC_CO_SBO_N_M
SBOW	SBOW	CO			AC_CO_SBOW_E_M
Oper	Oper	CO			AC_CO_M
Cancel	Cancel	CO			AC_CO_SBO_N_M and AC_CO_SBOW_E_M and AC_CO_TA_E_M
inherited data attributes					
All DataAttributes except those with FC=CO shall be inherited from the DPC class defined in IEC 61850-7-3.					
NOTE The DataAttributes in IEC 61850-7-3 with FC=CO and FC=ST will be treated in the following way: the DataAttribute with FC=ST will be inherited. The other will not be inherited.					

From IEC61850-8-1

For Select: SBO

Contains object name
e.g. CSWI1COPos$Oper

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SBOw Structure per 8-1

SBOw type definition			
Attribute name	Attribute type	Value/value range	M/O/C
ctlVal	Attribute type from base CDC		M for SPC, DPC, INC, BSC, and ISC
setMag	Attribute type from base CDC	c1	M for APC
operTm	TimeStamp	See 5.5.3.7 of IEC 61850-7-2	AC_CO_TA_E_M
origin	Originator	See 6.8 of IEC 61850-7-3	M
ctlNum	INT8U	0..255	M for SPC, DPC, INC, BSC, and ISC; attribute is not applicable for APC
T	See 17.5.2 of IEC 61850-7-2	See 17.5.2 of IEC 61850-7-2	M
Test	See 17.5.2 of IEC 61850-7-2	See 17.5.2 of IEC 61850-7-2	M
Check	See 17.5.2 of IEC 61850-7-2	See 17.5.2 of IEC 61850-7-2	M
c1 Only one attribute f or i shall be present at a given time for APC.			

From IEC61850-8-1

For SelectWithValue

Oper Structure per 8-1

Oper type definition			
Attribute name	**Attribute type**	**Value/value range**	**M/O/C**
ctlVal	Attribute type from base CDC		M for SPC, DPC, INC, BSC, and ISC
setMag	Attribute type from base CDC	c1	M for APC
operTm	TimeStamp	See 5.5.3.7 of IEC 61850-7-2	AC_CO_TA_E_M
origin	Originator	See 6.8 of IEC 61850-7-3	M
ctlNum	INT8U	0..255	M for SPC, DPC, INC, BSC, and ISC; attribute is not applicable for APC
T	See 17.5.2 of IEC 61850-7-2	See 17.5.2 of IEC 61850-7-2	M
Test	See 17.5.2 of IEC 61850-7-2	See 17.5.2 of IEC 61850-7-2	M
Check	See 17.5.2 of IEC 61850-7-2	See 17.5.2 of IEC 61850-7-2	M
c1 Only one attribute f or i shall be present at a given time for APC.			From IEC61850-8-1

Written by client to change the control value

Originator Structure

Originator Type Definition			From IEC61850-7-3
Attribute Name	**Attribute Type**	**Value/Value Range**	**M/O/C**
orCat	ENUMERATED	not-supported | bay-control | station-control | remote-control | automatic-bay | automatic-station | automatic-remote | maintenance | process	M
orIdent	OCTET STRING64		M

orCat – Category of Control Action
- 0 – not supported
- 1 – Bay Control
- 2 – Station Control
- 3 – Remote Control
- 4 – Automatic Bay
- 5 – Automatic Station
- 6 – Automatic Remote
- 7 – Maintenance
- 8 – Process

orIdent – Originator Identity (binary ID)

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Control Object Mapping per 8-1 for ctlModel = SBO Normal Security

DPC class					
Attribute Name	Attribute Type	FC	TrgOp	Value/Value Range	M/O/C
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute				From IEC61850-7-3	
control and status					
ctlVal	BOOLEAN	CO		off (FALSE) | on (TRUE)	AC_CO_M
operTm	TimeStamp	CO			AC_CO_O
origin	Originator	CO, ST			AC_CO_O
ctlNum	INT8U	CO, ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		AC_CO_O
substitution					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
configuration, description and extension					
pulseConfig	PulseConfig	CF			AC_CO_O
ctlModel	CtlModels	CF			M
sboTimeout	INT32U	CF			AC_CO_O
sboClass	SboClasses	CF			AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

SBO ← For Select

Oper.ctlVal
Oper.operTm
Oper. origin
Oper. ctlNum
Oper. T
Oper. Test
Oper. Check

For Operate

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Control Object Mapping per 8-1 for SBO with Enhance Security

DPC class					
Attribute Name	Attribute Type	FC	TrgOp	Value/Value Range	M/O/C
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute				From IEC61850-7-3	
control and status					
ctlVal	BOOLEAN	CO		off (FALSE) | on (TRUE)	AC_CO_M
operTm	TimeStamp	CO			AC_CO_O
origin	Originator	CO, ST			AC_CO_O
ctlNum	INT8U	CO, ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		AC_CO_O
substitution					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
configuration, description and extension					
pulseConfig	PulseConfig	CF			AC_CO_O
ctlModel	CtlModels	CF			M
sboTimeout	INT32U	CF			AC_CO_O
sboClass	SboClasses	CF			AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Oper.ctlVal
Oper.operTm
Oper.origin
Oper. ctlNum
Oper.T
Oper.Test
Oper.Check

For Operate

SBOw.ctlVal
SBOw.operTm
SBOw.origin
SBOw.ctlNum
SBOw.T
SBOw.Test
SBOw.Check

For Select with Value

Edition 2 Controls

8-1 SCSM Mapping results in the same control structures

DPC class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
status and control mirror					
origin	Originator	ST			AC_CO_O
ctlNum	INT8U	ST		0..255	AC_CO_O
stVal	CODED ENUM	ST	dchg	intermediate-state | off | on | bad-state	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
stSeld	BOOLEAN	ST	dchg		O
opRcvd	BOOLEAN	OR	dchg		O
opOk	BOOLEAN	OR	dchg		O
tOpOk	TimeStamp	OR			O
substitution and blocked					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	CODED ENUM	SV		intermediate-state | off | on | bad-state	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
configuration, description and extension					
pulseConfig	PulseConfig	CF	dchg		AC_CO_O
ctlModel	CtlModels	CF	dchg		M
sboTimeout	INT32U	CF	dchg		AC_CO_O
sboClass	SboClasses	CF	dchg		AC_CO_O
operTimeout	INT32U	CF	dchg		AC_CO_O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table 31					

parameters for control services		
Service parameter name	**Service parameter type**	**Value/Value range**
ctlVal	BOOLEAN	off (FALSE) | on (TRUE)

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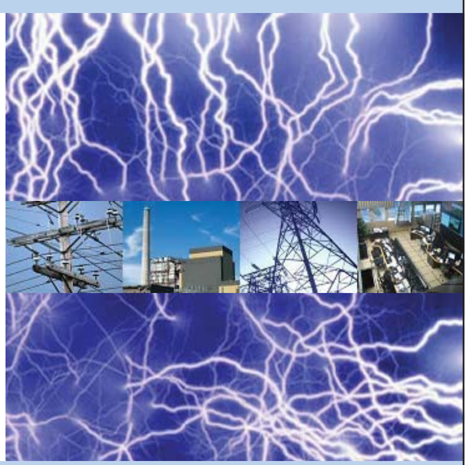

Examples

Changing Switch Positions Using Various Control Modes (CSWI1)

Direct Operate Normal Security

- Verify (optional)
  - Read CSWI1STPos$stVal (current position)
  - Read CSWI1CFPos$ctlModel (control model = 1)
- Operate:
  - Write CSWI1COPos$Oper
    - ctlVal, operTm, origin, ctlNum, T, Test, Check

Select Before Operate Normal Security

- Verify (optional)
  - Read CSWI1STPos$stVal (current position)
  - Read CSWI1STPos$stSeld (selected = 0)
  - Read CSWI1CFPos$ctlModel (control model = 2)
- Select:
  - Read CSWI1COPos$SBO (return: CSWI1$COPosOper)
- Operate:
  - Write CSWI1COPos$Oper
    - ctlVal, operTm, origin, ctlNum, T, Test, Check

SBO with Enhanced Security

- Verify (optional)
  - Read CSWI1STPos$stVal (current position)
  - Read CSWI1STPos$stSeld (selected = 0)
  - Read CSWI1CFPos$ctlModel (control model = 4)
- SelectWithValue:
  - Write CSWI1COSBOw
    - ctlVal, operTm, origin, ctlNum, T, Test, Check
- Operate:
  - Write CSWI1COPos$Oper
    - ctlVal, operTm, origin, ctlNum, T, Test, Check
- CmdTerm
  - (+) InformationReport containing CSWI1COPos$Oper
  - (-) InformationReport containing LastApplError and CSWI1COPos$Oper

Client Applications

- Typical bay controllers expose simple control commands such as Select-Operate or Operate.
- HMI screen developers can use ActiveX controls or scripts to embed the control state machine and functions within a simple interface
- Some IEC 61850 clients provide simplified operations that enable write of the ctlVal only.

Questions - Discussion

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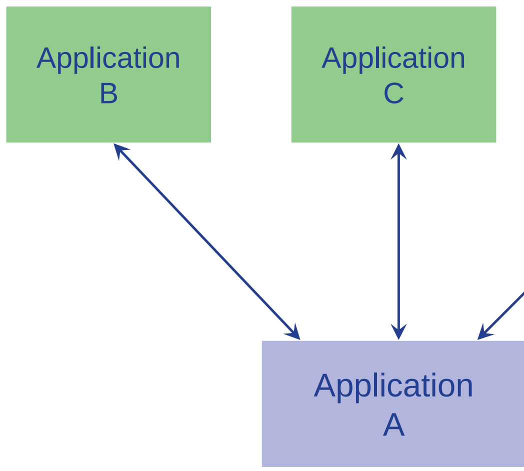
IED to IED Data Exchange

Multi-cast GOOSE Messaging

Directed Messaging



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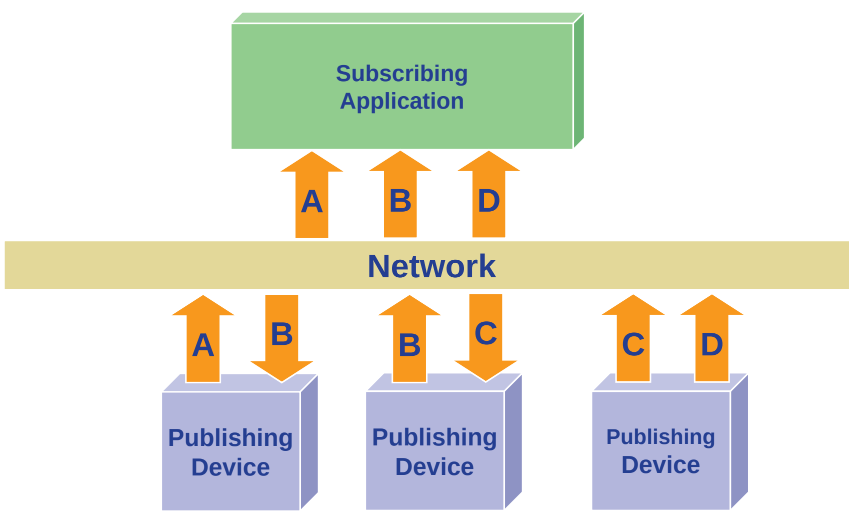
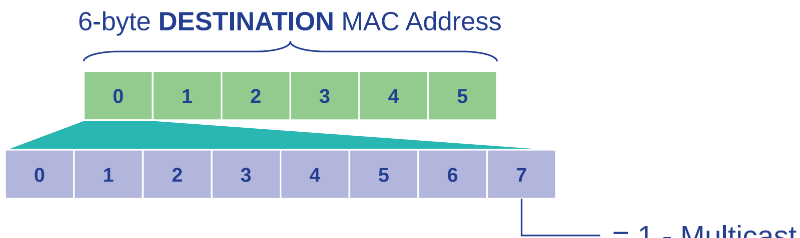
Multi-cast Messaging



Applications "subscribe" by listening for data sent to a given multi-cast destination address

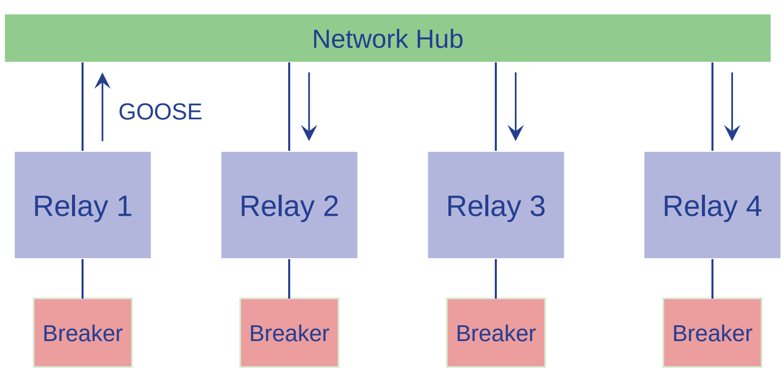
Multi-cast MAC Address



Example: 01-0C-CD-01-F1-04

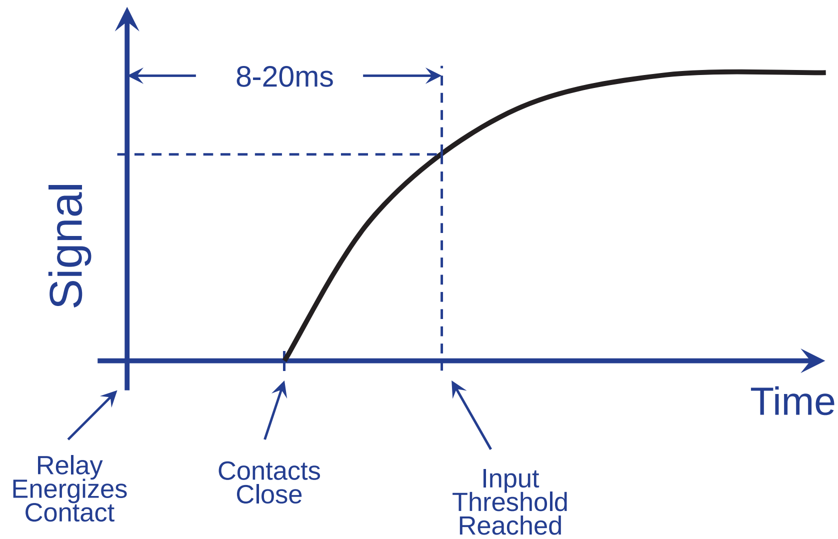
Service	Recommended address range assignments	
	Starting address (hexadecimal)	Ending address (hexadecimal)
GOOSE	01-0C-CD-01-00-00	01-0C-CD-01-01-FF
GSSE	01-0C-CD-02-00-00	01-0C-CD-02-01-FF
Multicast sampled values	01-0C-CD-04-00-00	01-0C-CD-04-01-FF

IEC61850 Network Architecture



GOOSE - Generic Object Oriented Substation Event (data sets)

Hardwired Performance



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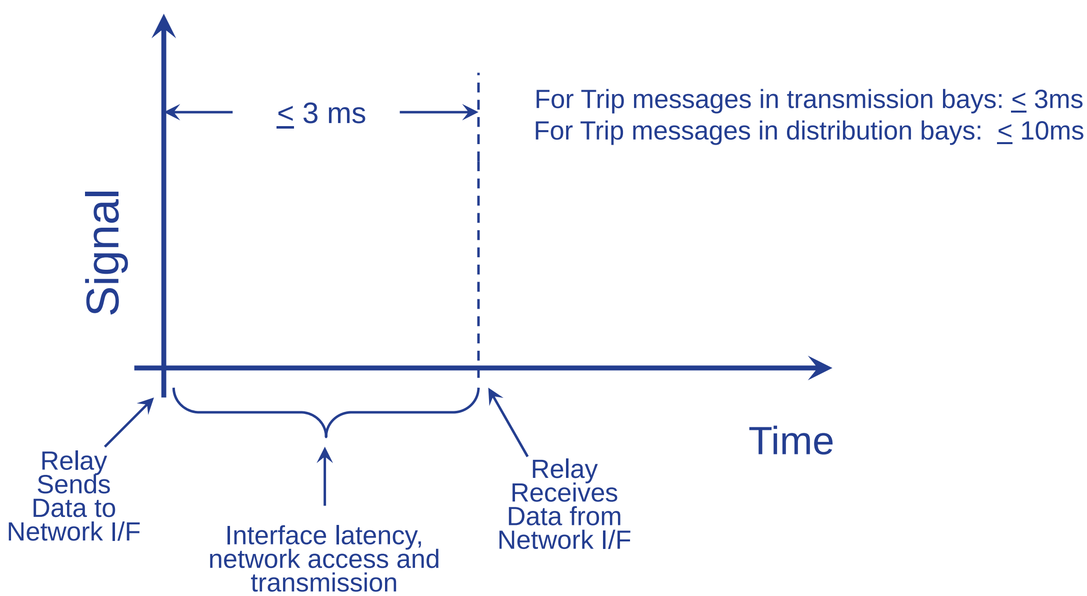
IEC 61850 GOOSE Network Performance Requirements



GOOSE - Generic Object Oriented Substation Event per 7-2

GOOSE message		
Parameter name	**Parameter type**	**Value/value range/explanation**
DatSet	ObjectReference	Value from the instance of GoCB
GoID	VISIBLE STRING129	Value from the instance of GoCB
GoCBRef	ObjectReference	Value from the instance of GoCB
T	TimeStamp	
StNum	INT32U	
SqNum	INT32U	
Simulation (Edition 2)	BOOLEAN	(TRUE) simulation | (FALSE) real values
ConfRev	INT32U	Value from the instance of GoCB
NdsCom	BOOLEAN	Value from the instance of GoCB
GOOSEData [1..n]		
Value	(*)	(*) type depends on the appropriate common data classes (CDC).

Binary encoding of data

Ethernet Multicast Address Using 802.3 Ethertype

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GOOSE - 7-2 versus 8-1

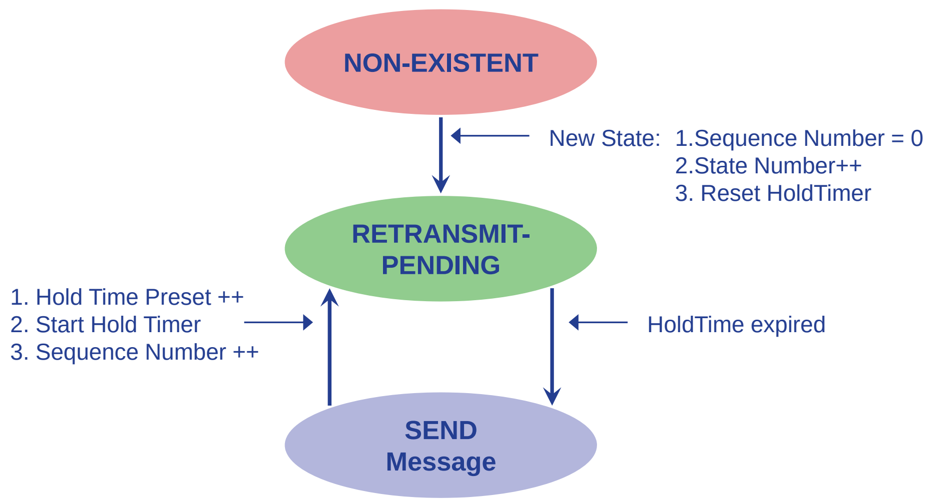
7-2 Message Fields

Name	Type
DatSet	ObjectReference
GoID	VISIBLESTRING129
GoCBRef	ObjectReference
T	TimeStamp
StNum	INT32U
SqNum	INT32U
Simulation	BOOLEAN
ConfRev	INT32U
NdsCom	BOOLEAN
Data	per DataSet Def'n.

8-1 Message Fields

Name	Type
gocbRef	VISIBLE-STRING
timeAllowedtoLive	Integer (ms)
datSet	VISIBLE-STRING
goID	VISIBLE-STRING
T	UTC Time
stNum	INTEGER
sqNum	INTEGER
Simulation	BOOLEAN
confRev	INTEGER
ndsCom	BOOLEAN
numDatSetEntries	INTEGER
Data	per DataSet Def'n.

GOOSE is Reliable Multicast



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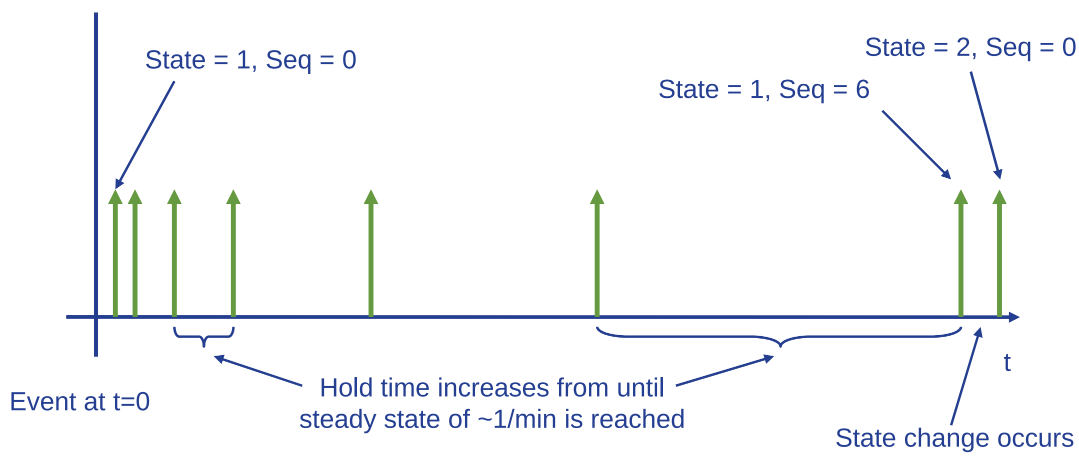
GOOSE Traffic

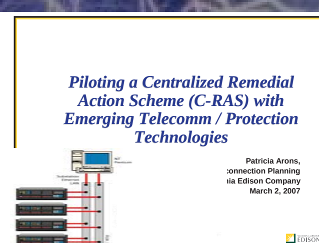
Each line below represents a GOOSE message



Why Ethertype?

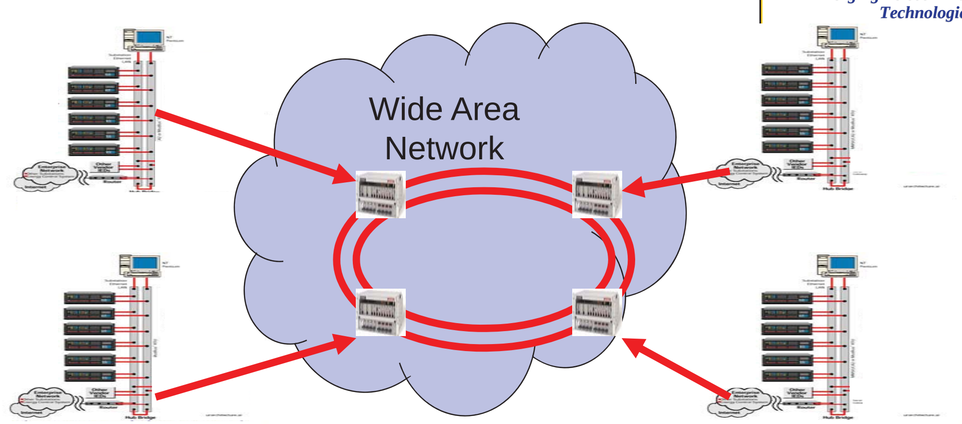
- Supports Virtual LAN (VLAN) processing by switches.
- VLAN enables intelligent 3-layer Ethernet switches to prioritize packets via VLAN Priority.
- Enables high priority GOOSE packets to be forwarded sooner than lower priority directed messages (SCADA).

GOOSE Wide Area Application


Piloting a Centralized Remedial Action Scheme (C-RAS) with Emerging Telecomm / Protection Technologies

Patricia Arons,

March 2, 2007



Application of VLAN Critical

GOOSE Unicast Services

- Provided for devices that support GOOSE/GSSE but do not support LNs and other ACSI services.
- Enables a device to obtain information about the data that is sent in a GOOSE/GSSE to verify that it is the desired data without having to implement ACSI services and objects.
- Also called “GSE Management” services.

GOOSE Control Block (GoCB) and Services per 7-2

GoCB class — From IEC61850-7-2

Attribute name	Attribute type	FC	TrgOp	Value/value range/explanation
GoCBName	ObjectName	GO	-	Instance name of an instance of GoCB
GoCBRef	ObjectReference	GO	-	Path-name of an instance of GoCB
GoEna	BOOLEAN	GO	dchg	Enabled (TRUE) | disabled (FALSE)
AppID	VISIBLE STRING65	GO		Attribute that allows a user to assign a system unique identification for the application that is issuing the GOOSE. DEFAULT GoCBRef
DatSet	ObjectReference	GO	dchg	
ConfRev	INT32U	GO	dchg	
NdsCom	BOOLEAN	GO	dchg	

From IEC61850-7-2

Service	Description
SendGOOSEMessage	Send GOOSE message
GetGoReference	Retrieve the **FCD/FCDA** of a specific member of **DATA-SET** associated with the GOOSE message
GetGOOSEElementNumber	Retrieve the position of the member in the **DATA-SET** associated with the GOOSE message of a **FCD/FCDA**
GetGoCBValues	Retrieve the attributes of a **GoCB**
SetGoCBValues	Write the attributes of a **GoCB**

GOOSE Multicast | GOOSE Unicast | ACSI Client/Server

GOOSE Control Block per 8-1

Component Name	MMS TypeDescription	r/w	m/o	Condition	Comments
GoEna	Boolean	rw	m		
GoID	Visible-string	r	m		
DatSet	Visible-string	r	m		The value of this component shall be of the format of ObjectReference and shall be limited to VMD or domain scoped NamedVariableLists
ConfRev	Unsigned	r	m		
NdsCom	Boolean	r	m		
DstAddress	PHYCOMADDR	r	m		
MinTime	Unsigned	r	o		As specified in the SCD file for the GoCB
MaxTime	Unsigned	r	o		As specified in the SCD file for the GoCB
FixedOffs	Boolean	r	o		As specified in the SCD file for the GoCB

Component Name	Data Type	m/o	Comments
Addr	OCTET-STRING	m	Length is 6 Octets and contains the value of the destination Media Access Control (MAC) address to which the GOOSE message is to be sent. The address shall be an Ethernet address that has the multicast bit set TRUE.
PRIORITY	Unsigned8	m	Range of values shall be limited from 0 to 7.
VID	Unsigned16	m	Range of values shall be limited from 0 to 4 095.
APPID	Unsigned16	m	As defined in Annex C

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Substation Configuration Language

SCL
IEC61850-6

SCL – Substation Configuration Language IEC61850-6-1

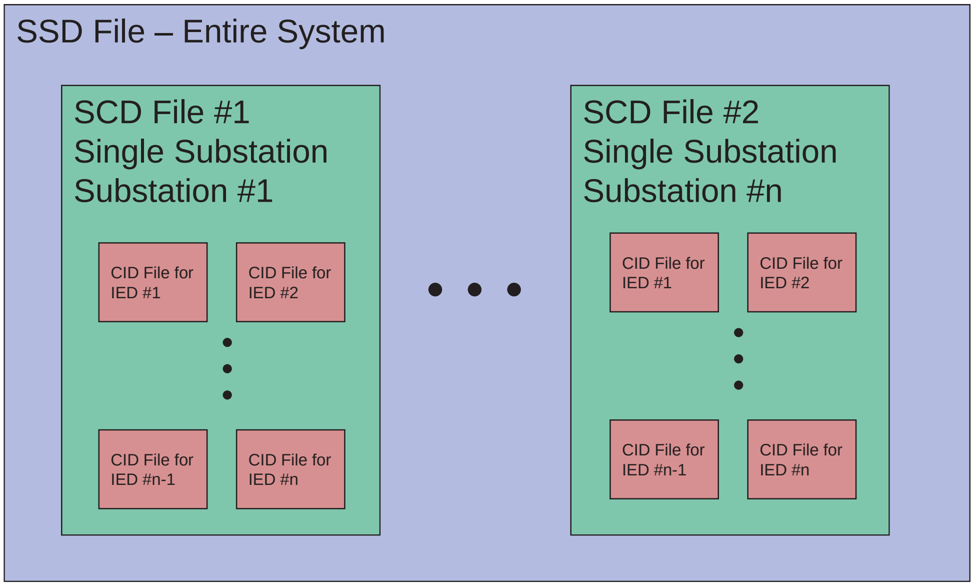
- Description language for communication in electrical substations related to the IEDs.

- XML based language that allows a formal description of
  - Substation automation system and the switchyard and the relation between them
  - IED configuration
  - Support for private extensions

SCL File Types

- **SSD**: System Specification Description.
  - XML description of the entire system
- **SCD**: Substation Configuration Description.
  - XML description of a single substation.
- **IID**: Instantiated IED Description (Edition 2)
  - XML description of a device that meets specific project needs but that has not yet been configured. An initial starting point.
- **CID**: Configured IED Description.
  - XML configuration for a specific IED.
- **SED**: System Exchange Description (Edition 2)
  - Subset of SCD file that specifies responsibilities between entities implementing different parts of a project
- **ICD**: IED Capability Description.
  - XML description of what is supported by an IED (required for servers).

SCL Files



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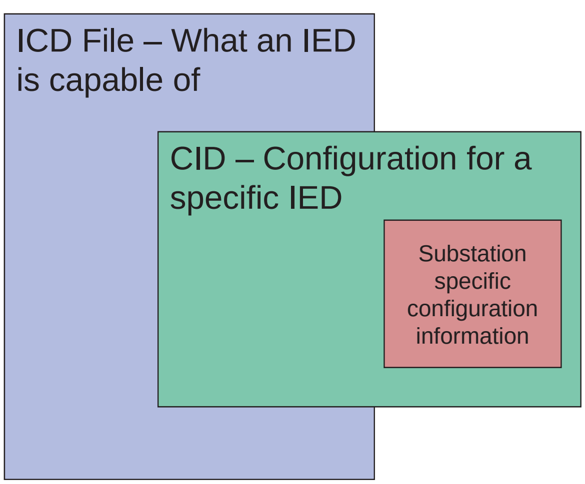
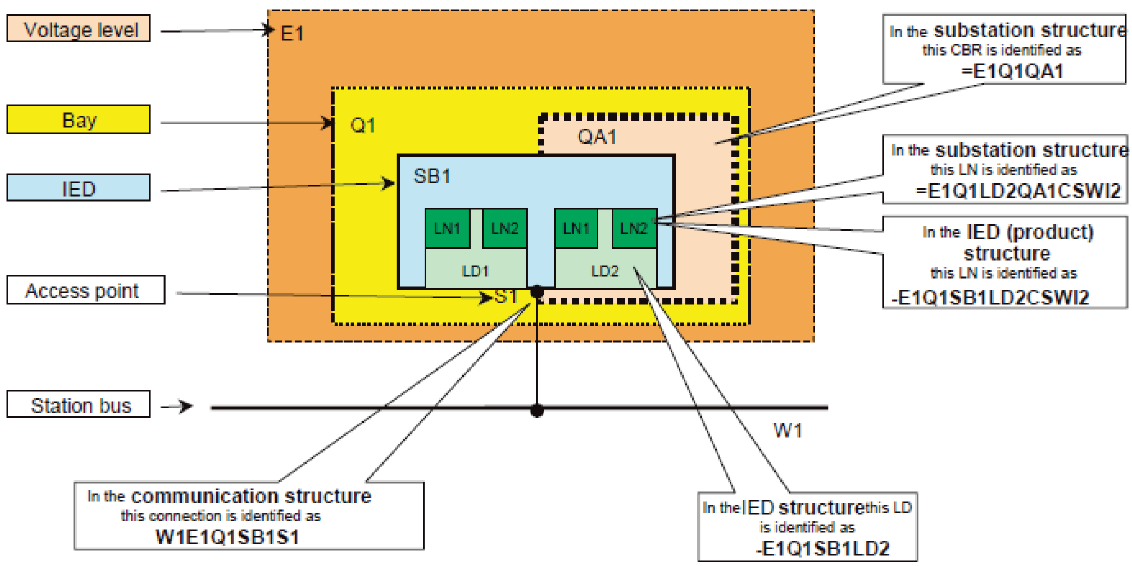
ICD versus CID Files



- CID File = Subset of ICD File Actually Used + Substation Specific Configuration Info.
- Subset:
  - Not all logical nodes, control blocks, I/O, etc. supported by the device are used in a system.
- Substation Configuration Info:
  - Report control block presets
  - Static values for location, and other descriptions.

SCL Driven Naming



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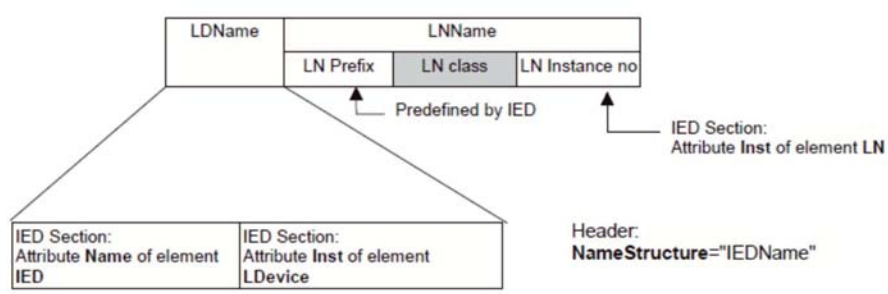
Logical Device and LN Naming = IEDName



SCL Applications

- For users to specify IED requirements.
- For vendors to specify IED capabilities.
- Configure IEC61850 clients w/o IEDs.
- Extract IED configuration from power system design tools.
- Export IED configuration to power system design tools and other applications.

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Process Bus and Sampled Values

Process Bus
IEC61850-9-2

Sampled Values

- A method for transmitting sampled measurements from transducers such as CTs, VTs, and digital I/O.
- Enables sharing of I/O signals among IEDs
- Supports 2 transmission methods:
  - **Multicast service (MSVC) over Ethernet (9-2)**
  - Unicast (point-to-point) service (USVC) over serial links (based on Ethernet) (9-1)

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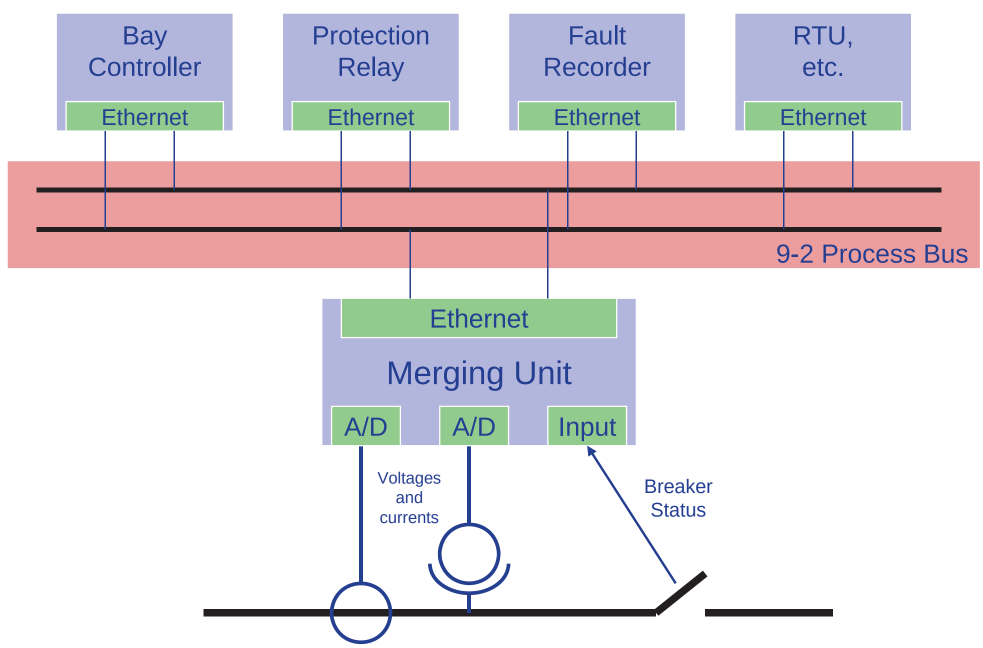
IEC61850 Approach



IEC61850-9-2 Process Bus

- Transducer and I/O signals are shared via a network.
- Only one transducer or I/O point per signal.
- Reduction in wiring costs
  - 4 fibers per bus (2 per redundant pair) versus many copper wires per phase
- Minimization of calibration and maintenance.
- Incremental cost for additional signals is linear
  - Pay to add a measurement once to a single Merging Unit
- CT/VT signals can be sent across long distances

SV Object – Edition 1

From IEC61850-7-2

Sampled value format

Parameter name	Parameter type	Value/value range/explanation
MsvID or **UsvID**	VISIBLE STRING65	Value from the **MSVCB** or **USVCB**
OptFlds	from **USVCB** or **MSVCB**	Optional fields to be included in the SV message
DatSet	ObjectReference	Value from the **MSVCB** or **USVCB**
Sample [1..n]		
Value	(*)	(*) The value of the member of the instance of the **DATA-SET**. Type of the common data classes is **SAV** (sampled analogue value) as defined in IEC 61850-7-3
SmpCnt	INT16U	Sample counter
RefrTm	EntryTime	OPTIONAL; time of refresh activity
ConfRev	INT32U	Configuration revision number from the instance of **MSVCB** or **USVCB**
SmpSynch	BOOLEAN	OPTIONAL; samples are synchronized by clock signals
SmpRate	INT16U	OPTIONAL; sample rate from the instance of **MSVCB** or **USVCB**

Binary encoding of data

Ethernet Multicast Address Using 802.3 Ethertype

SV Control Block (MSVCB) and Services Edition 1

MSVCB class				From IEC61850-7-2
Attribute name	**Attribute type**	**FC**	**TrgOp**	**Value/value range/explanation**
MsvCBNam	ObjectName	-	-	Instance name of an instance of **MSVCB**
MsvCBRef	ObjectReference	-	-	Path-name of an instance of **MSVCB**
SvEna	BOOLEAN	MS	dchg	Enabled (TRUE) | disabled (FALSE), DEFAULT FALSE
MsvID	VISIBLE STRING65	MS	-	
DatSet	ObjectReference	MS	dchg	
ConfRev	INT32U	MS	dchg	
SmpRate	INT16U	MS	-	(0..MAX)
OptFlds	PACKED LIST	MS	dchg	
refresh-time	BOOLEAN			
sample-synchronized	BOOLEAN			
sample-rate	BOOLEAN			

Service	**Description** (From IEC61850-7-2)
SendMSVMessage	Send MSV message
GetMSVCBValues	Retrieve the attributes of an **MSVCB**
SetMSVCBValues	Write the attributes of an **MSVCB**

GOOSE Multicast ACSI Client/Server

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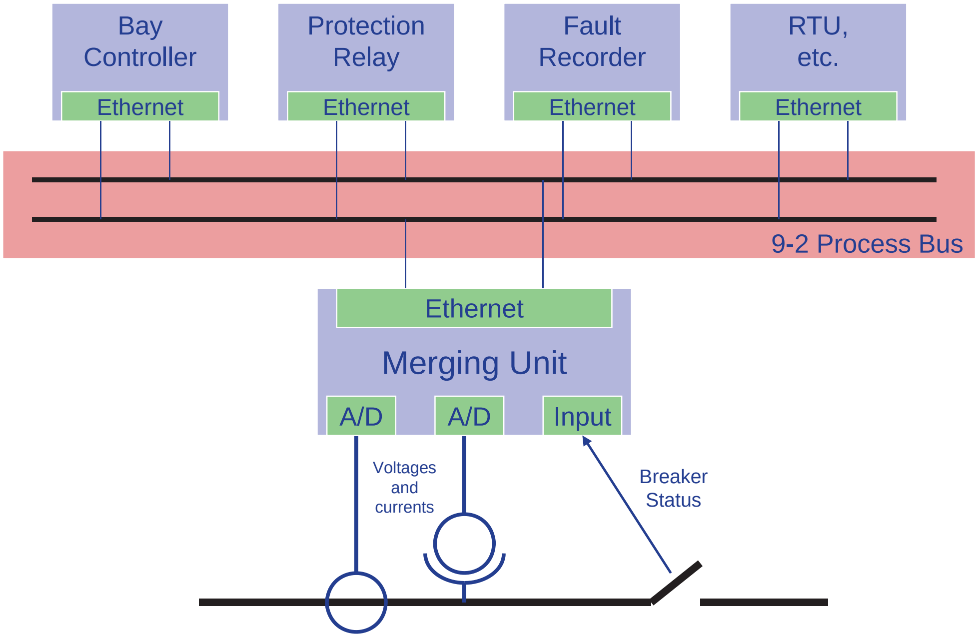
SV Control Block (MSVCB) – Edition 2

MSVCB class			
Attribute name	**Attribute type**	**r/w**	**Value/value range/explanation**
MsvCBName	ObjectName	-	Instance name of an instance of **MSVCB**
MsvCBRef	ObjectReference	-	Path-name of an instance of **MSVCB**
SvEna	BOOLEAN	r/w	Enabled (TRUE) | disabled (FALSE), DEFAULT FALSE
MsvID	VISIBLE STRING129	r/w	
DatSet	ObjectReference	r/w	
ConfRev	INT32U	r	
SmpMod	ENUMERATED	r/w	samples per nominal period (DEFAULT) | samples per second | seconds per sample
SmpRate	INT16U	r/w	(0..MAX)
OptFlds	PACKED LIST	r/w	
refresh-time	BOOLEAN		
reserved	BOOLEAN		
sample-rate	BOOLEAN		
data-set-name	BOOLEAN		
DstAddress	PHYCOMADDR	r	

What is a bus?



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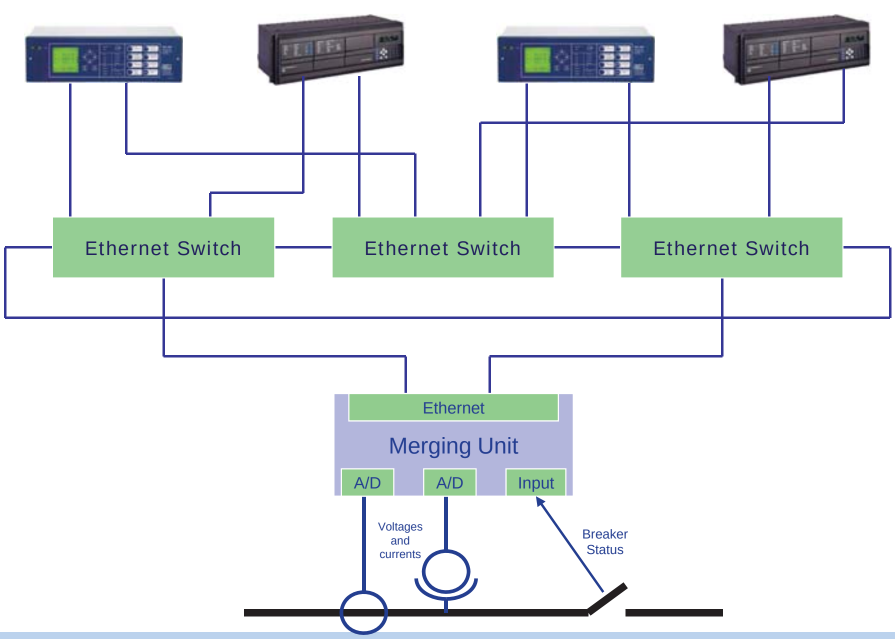
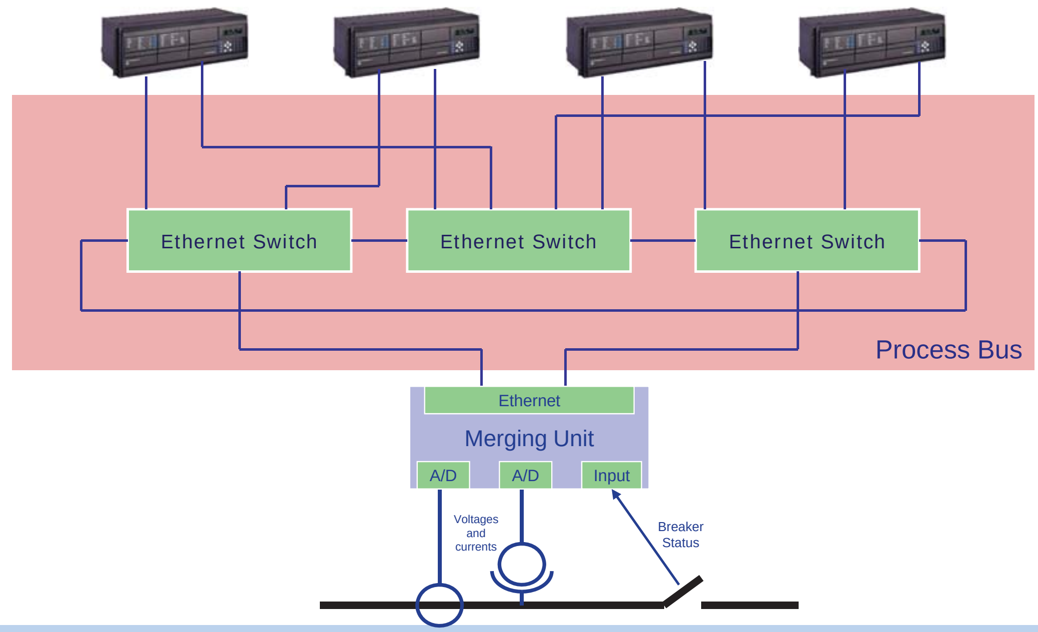
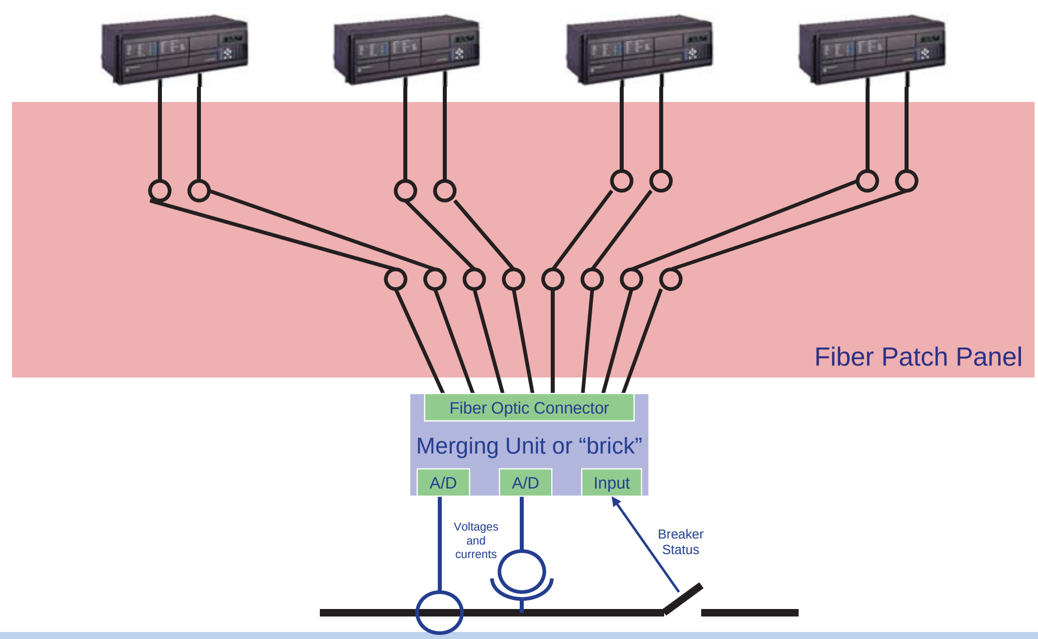
What is a Bus?



What is a Bus?



New Development in Process Bus – point-to-point!?



Point-to-Point Process Bus – Controversy

- Some say 9-2 does not specify point-to-point links:
  - Therefore this is NOT process bus!
- Existing implementations of this technology have some non-interoperable "enhancements"
  - Requires interaction with special GOOSE messages to trigger MU
- Initial claims about "conformance testing" were made inaccurately (since corrected).
- Interesting idea and useful even if it is not strictly 9-2 process bus.

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IEC 61850-90-5

- Using IP Multicast to transmit GOOSE and/or Sampled Values
- Synchrophasor and wide area protection
- Will be issued as a technical report in 2011.
- Implementations coming as well.

Questions - Discussion

Tutorial
11

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Testing

Interoperability and Conformance

Interoperability

- Testing that multiple devices or multiple applications of different design can exchange information
- Interoperability and Integration is the fundamental user expectation when they purchase a system
  - All components can exchange data and cooperate in the implementation of the system requirements
- A system acceptance test is essentially an interoperability and integration test.
- Interoperability testing is always the first step in proving a standard.

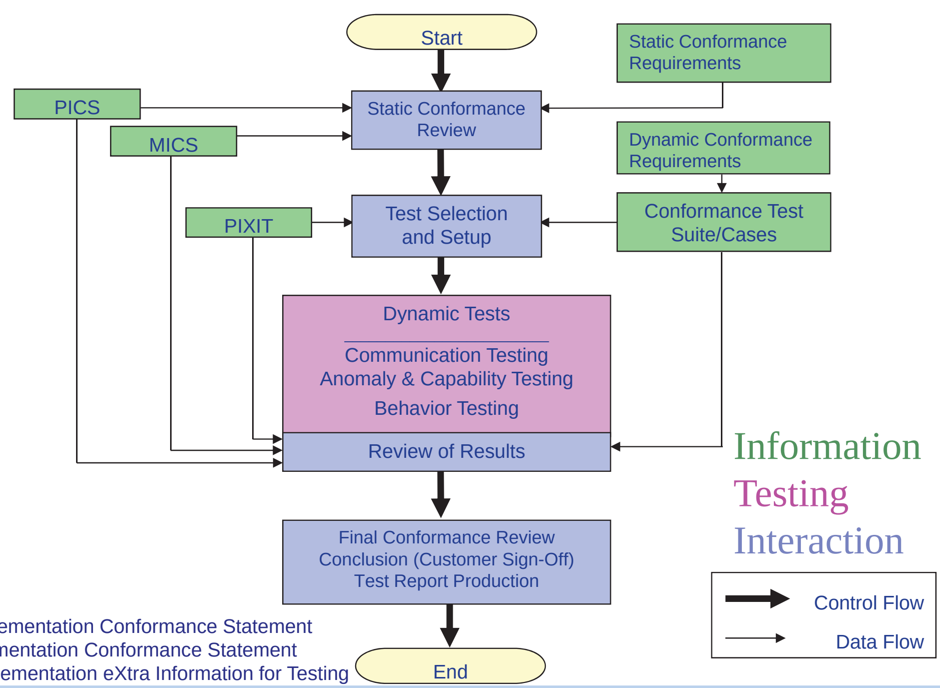
Limitations of Interoperability Testing

- Only the functions of the current applications are tested
  - Adding new functions may not be as testable due to current operations.
- New systems not tested with existing applications may not interoperate
  - All possible combinations of interoperability tests between a set of available applications may not be performed.
- All tested systems may be non-conformant in the same way
  - 2 apps have the same non-conformance problem may interoperate with each other but not with other systems that are conformant.

Conformance Testing

- A formalized test that verifies conformance to the standard
- Typically a reference test system is created and devices/apps must interoperate with the tester.
- Conformance testers are written with the standard in mind
  - Interoperability tests are typically written with the application in mind
- Conformance testers will also test negative/error test cases.
- Conformance testing will increase the likelihood that applications will interoperate

IEC61850-10 Test Process



PICS – Protocol Implementation Conformance Statement
MICS – Model Implementation Conformance Statement
PIXIT – Protocol Implementation eXtra Information for Testing

Sample Test Cases

6.3.4.6 Application association

6.3.4.6.1 Positive

From IEC61850-10

Test case	Test case description
Ass1	Associate and release a TPAA association (IEC 61850-7-2 clause 7.4)
Ass2	Associate and server-abort TPAA association (IEC 61850-7-2 clause 7.4)
Ass3	Associate and client-abort TPAA association (IEC 61850-7-2 clause 7.4)
Ass4	Associate with maximum number of clients simultaneously (PIXIT)

6.3.4.6.2 Negative

Test case	Test case description
AssN1	Check that with incorrect authentication parameters and authentication turned on at server the association fails, and with authentication turned off the server associates (IEC 61850-7-2 clause 7.4)
AssN2	Check that with incorrect association parameters at server or client the association fails (IEC 61850-7-2 clause 7.4, PIXIT)
AssN3	Set up maximum+1 associations, verify the last associate is refused
AssN4	Disconnect the communication interface, the DUT shall detect link lost within a specified period
AssN5	Interrupt and restore the power supply, the DUT shall accept an association request when ready

Sample Test Cases

6.3.4.7.2 Negative

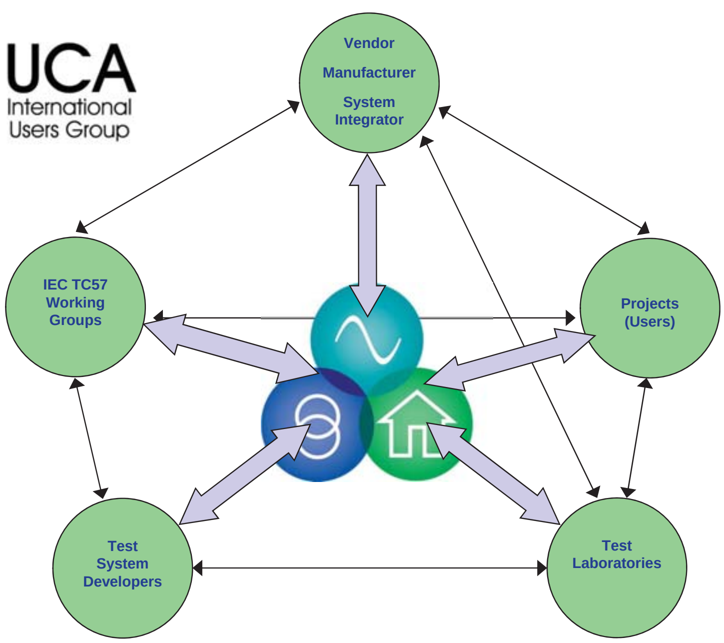
From IEC61850-10

Test case	Test case description
SrvN1	Request following data services with wrong parameters (unknown object, name case mismatch, wrong logical device or wrong logical node) and verify response- service error – ServerDirectory(LOGICAL-DEVICE) (IEC 61850-7-2 clause 6.2.2) – GetLogicalDeviceDirectory (IEC 61850-7-2 clause 8.2.1) – GetLogicalNodeDirectory(DATA) (IEC 61850-7-2 clause 9.2.2) – GetAllDataValues (IEC 61850-7-2 clause 9.2.3) – GetDataValues (IEC 61850-7-2 clause 10.4.2) – SetDataValues (IEC 61850-7-2 clause 10.4.3) – GetDataDirectory (IEC 61850-7-2 clause 10.4.4) – GetDataDefinition (IEC 61850-7-2 clause 10.4.5)
SrvN2	Request SetDataValues of CODED ENUM data with out-of-range value and verify response-service error (IEC 61850-7-2 clause 10.4.2)
SrvN3	Request SetDataValues with mismatching data type (e.g. int-float) and verify response- service error (IEC 61850-7-2 clause 10.4.2)
SrvN4	Request SetDataValues for read-only data values and verify response- service error (IEC 61850-7-2 clause 10.4.2)

Certification

- A statement that tests have been run:
  - Who ran the tests
  - What tests have been run
  - How the results were determined
- An independent third party should certify that the tester is valid and that the process used by a test lab is valid.
- Certifying body must provide a **quality assurance process** to improve the testing, fix the standards, and increase field interoperability

UCA IUG Quality Assurance Process



Limitations of Conformance Testing

- Essentially, interoperation with the tester is verified.
  - Possible that 2 conformant applications may not interoperate for a variety of reasons.
  - Importance of the quality assurance process to improve testing over time.
- Applications can be configured differently to behave in a different manner that is independent of conformance.
- 2 Protection Relays:
  - IED 1: uses an XML file generated by the user to configure the IEC 61850 information that is sent to other relays.
  - IED 2: has a fixed configuration of specific data that can be sent to other relays.
  - Both are conformant
  - Unless IED 1 is modified to support the configuration of IED 2 they will not interoperate.
- Interoperability testing is still useful

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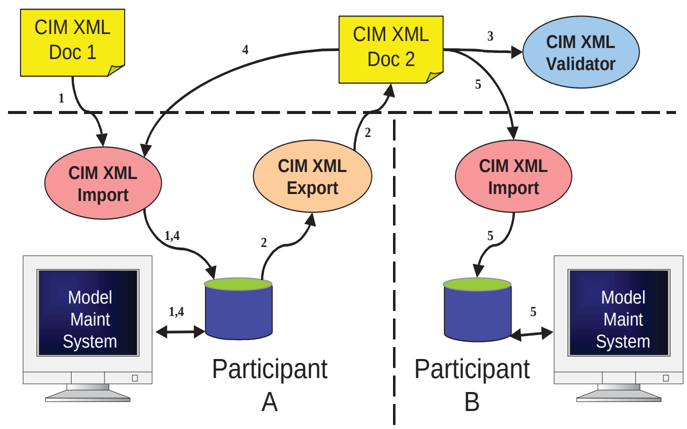
CIM Testing

- While the fundamentals of power systems are the same each utility is a unique enterprise that has a different model:
  - Completely different business systems
  - Different business processes and rules
  - Different regulations, requirements, customers
  - Very little is the same other than the fundamentals of the power system.
- The closeness of CIM to the business operations of the enterprise makes each utility's use of CIM different.
- Makes conformance testing of a given model difficult.
- The result is that CIM testing is focused on interoperability testing of exchange of models and messages conforming to a specific profile chosen for the test.

Model Exchange Test Cases



CIM Testing Organizations

- Electric Power Research Institute (EPRI) has sponsored many interoperability tests.
  - Model Exchange (CPSM, CDPSM, planning, dynamics)
  - GID testing (HSDA and OPC)
  - Message Exchange for IEC 61968-9
  - Reports are available from EPRI and some from the CIM Users Group web site
- ENTSO-E the European grid operator is planning on conducting further tests for its profile in 2010
- CIM Users Group is likely to sponsor additional tests in the future as well

IEC 61850-90-5

Next Generation GOOSE and SV over IP Multicast for Wide Area Measurement and Protection

C37.118.2 and beyond

Use cases documented in 90-5

- WAMS/WAMPAC related
  - WAMS
    - Situational Awareness
    - State Estimation and on-line security assessment
    - Archival of information
  - WAMPAC
    - Special protection schemes
    - Predictive Dynamic Stability
    - Phenomenon assumption WAMPAC

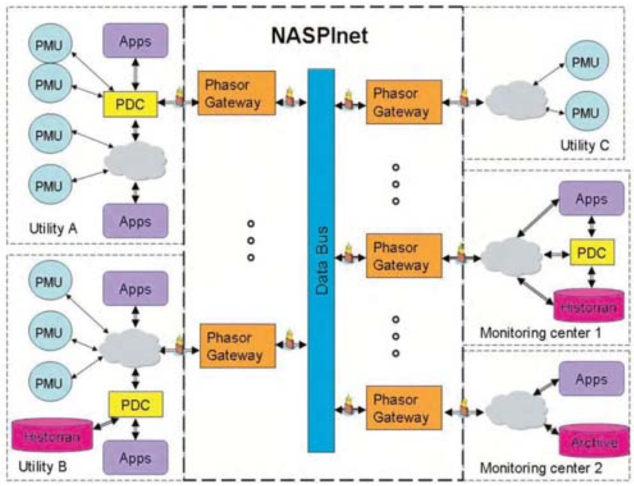
Use cases documented in 90-5

- “regional”/local related
  - Out-of-step (OOS) protection
  - Adaptive relaying
  - Synchro-check
  - Under-voltage shedding
- NASPINET (covered by others)
- PDC use case to be added.

90-5 development asked: Why so many PDCs?

- Answer:
  - C37.118.2 protocol not designed to scale from a communication perspective.
  - Time alignment function (it is good and bad).

NASPInet - Requirements

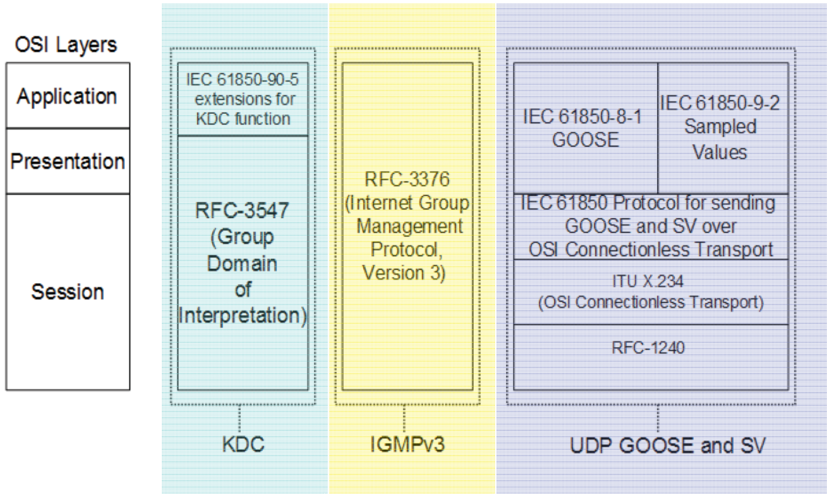


Decided to use IP multicast to address large scale of NASPInet.

To meet the use cases:

- Services explicitly specified in IEC 61850-90-5
  - GOOSE
  - SV
- Reporting and logging are implicitly allowed.
- Profile supports IP Multicast

IEC 61850-90-5 has several different profiles



Security Key Management Key Distribution Center (KDC)

Multicast Route Determination

Data Transfer

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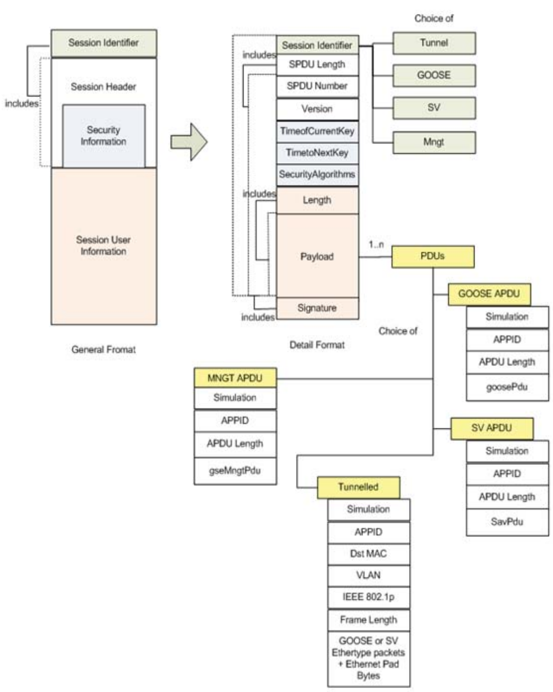


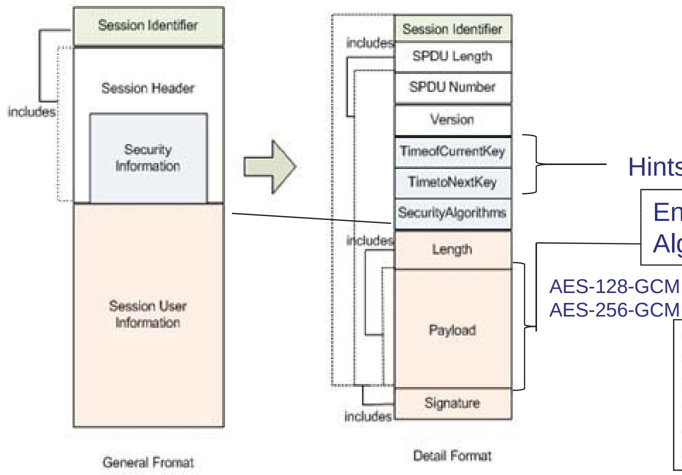
Data Transfer – Session Layer

Session can carry:

Individual GOOSE messages
Individual SV messages
Re-encapulated GOOSE/SV messages
Individual Mngt PDUs
Aggregates (e.g. PDC aggregation function) of:
- GOOSE
- SV
- Encapsulations
- Mngt

IP Multicast services: GOOSE, SV, Tunnel
IP Unicast services: Mngt

Data Transfer – Session Layer Security



Hints regarding Key rotation

Encryption Algorithm	Signature Algorithm

None	None	MAC-None	c1
SHA-256	80	HMAC-SHA256-80	m
SHA-256	128	HMAC-SHA256-128	m
SHA-256	256	HMAC-SHA256-256	m
AES-GMAC	64	AES-GMAC-64	m
AES-GMAC	128	AES-GMAC-128	m

Key management/exchange done
out-of-band through GDOI profile/protocol

Group Domain of Interpretation (GDOI): Phase 1

- Utilizes client certificate exchange to establish identity
- Asymetric keys are used to establish a secure path betweeen 2 nodes for exchange of key information.
- Symmetric keys used to encrypt TCP/IP packets.
- Similar to how TLS is used for ICCP-TASE.2

GDOI Phase 2

- Once access to the KDC is authenticated, subscriber requests a policy for a security association (SA) to an IED:
  - Type of communications (GOOSE or SV)
  - Data Set being transmitted

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GDOI Phase 3

- Assuming the client is authorized to access, the KDC responds with GDOI Security Association Payload (SA):
  - The Current Key Encrypting Key (KEK) in use by the PMU/PDC
    - KEK is a symmetric key used to authenticate data received by the client that is in current use by the PMU/PDC
  - Next KEK that is to be used
  - Time remaining on current KEK
- Client receives the IEC 61850-90-5 payloads separately using IP Multicast and authenticates using the KEK.
  - Must occassionaly reinstate GDOI phases to keep keys up to date.

Where should the KDC function be placed?

In the device — No redundancy required. Can only serve information for the device.

External to device — Redundancy required. Can serve information for the device.

IEC 61850-90-5 SCL modifications allow either approach to be described.

90-5 also recognized:

- No way for a C37.118.2 client to configure a server for what data needs to be delivered.
  - 90-5 makes use of SCL.
- Did not want to re-develop measurement techniques.
  - References C37.118.1
- Need to support streaming and events (based upon use cases).
- Need to support other data besides synchrophasor measurements.

How to migrate from C37.118 to IEC 61850-90-5

C37.118		61850	
Current State + Error Corrections	C37.118 Initial Migration	"Lite" 61850	"Full" 61850
Enable/Disable data frames	+ SCL CID file	Preconfigured in SCL CID file and automatically enabled.	Control Blocks + SCL
Header exchange	+ SCL CID File (description fields) for C37.118 have header information)	SCL CID File (description fields)	File Transfer + SCL CID File (description fields)
CFG-1 Exchange	+ SCL ICD File	SCL ICD File	SCL ICD File + Discovery
CFG-2 Exchange	+SCL CID File	SCL CID File	SCL CID File + DataSets + DataObjects
Extended Frame	No migration indicated	Not Standardized but could use GOOSE or other 61850 Mechanism	Not Standardized but could use GOOSE or other 61850 Mechanism
Data Frame	No change	GOOSE or SV over UDP/IP	GOOSE or SV over UDP/IP

IEC 61850-90-5

- Allows for transmission of time aligned and non-time aligned information (e.g. multiple PDU transmission support).
- Use of UDP/IPv4/IPv6 allows for the use of multicast addresses,
- Should allow for "late" information to be delivered.
- Will support event driven messaging and streaming.

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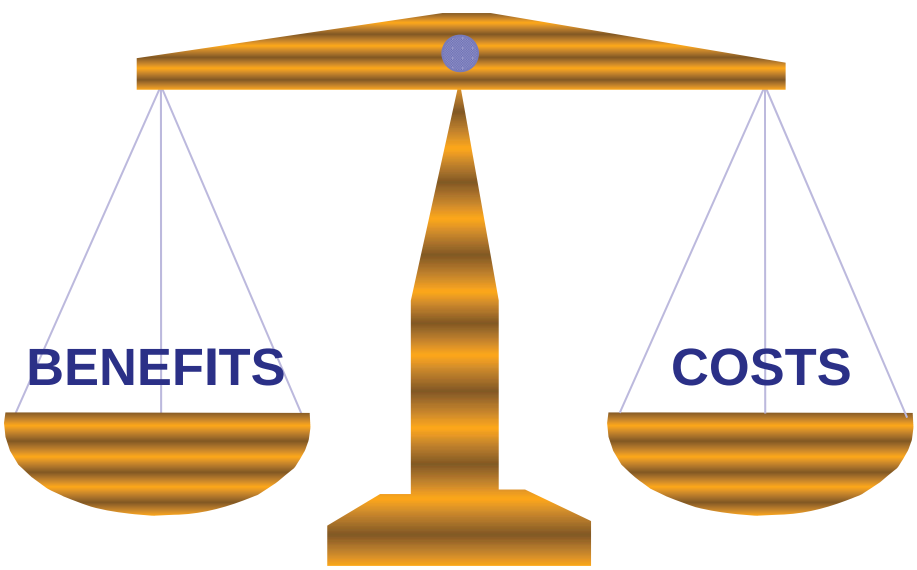
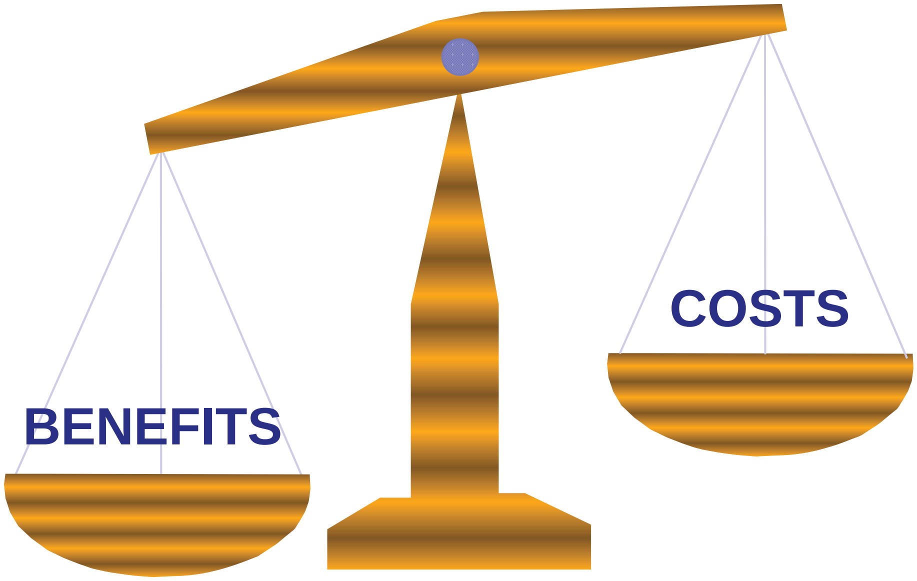
How Do You Make This Work In Your Enterprise?

Business Justification

The Justification Dilemma

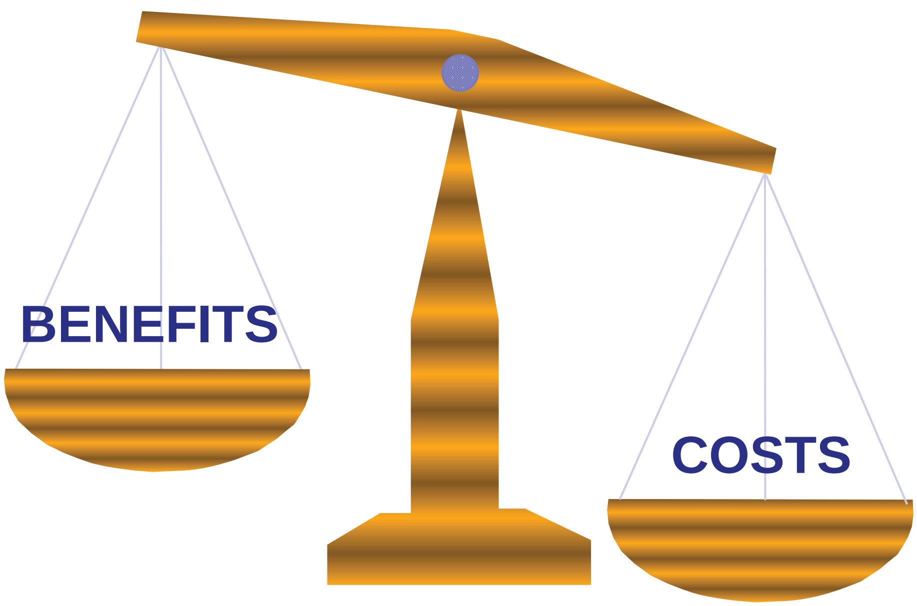


The Justification Dilemma



Engineer's View of Justification

The Justification Dilemma



Accountant's View of Justification

The Tragedy of Integration and Automation

There are no benefits
without some cost

About Benefits & Justification

- To identify the benefits it is necessary to identify ALL the costs:
  - Equipment
  - Installation
  - Design
  - Commissioning and Testing
  - Utilization Costs over Time
  - Impact on External Systems
  - **Costs to Change/Migrate in Future**
  - Intangibles (new capability – response to changes)
- Requires a complete view of cost beyond the initial price.
- Requires a longer time frame.

There is no benefit in buying something.

The benefit is in using it to improve operations AFTER the purchase.

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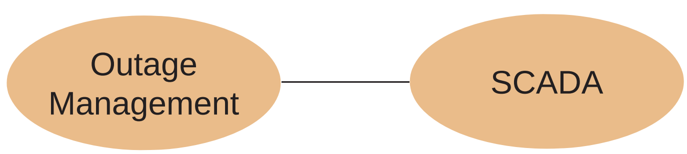
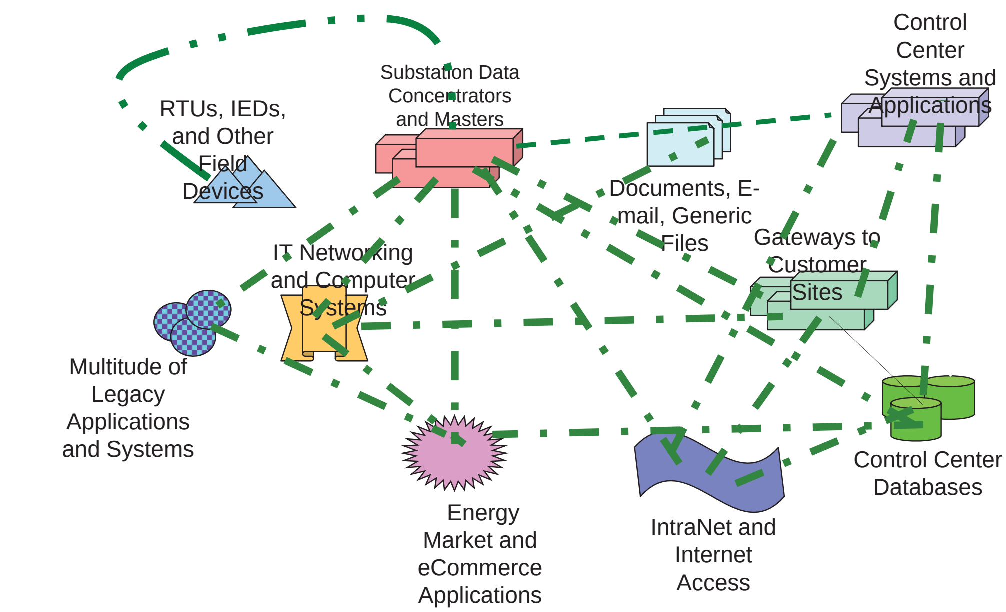
Cost Justification – Small Use Cases?

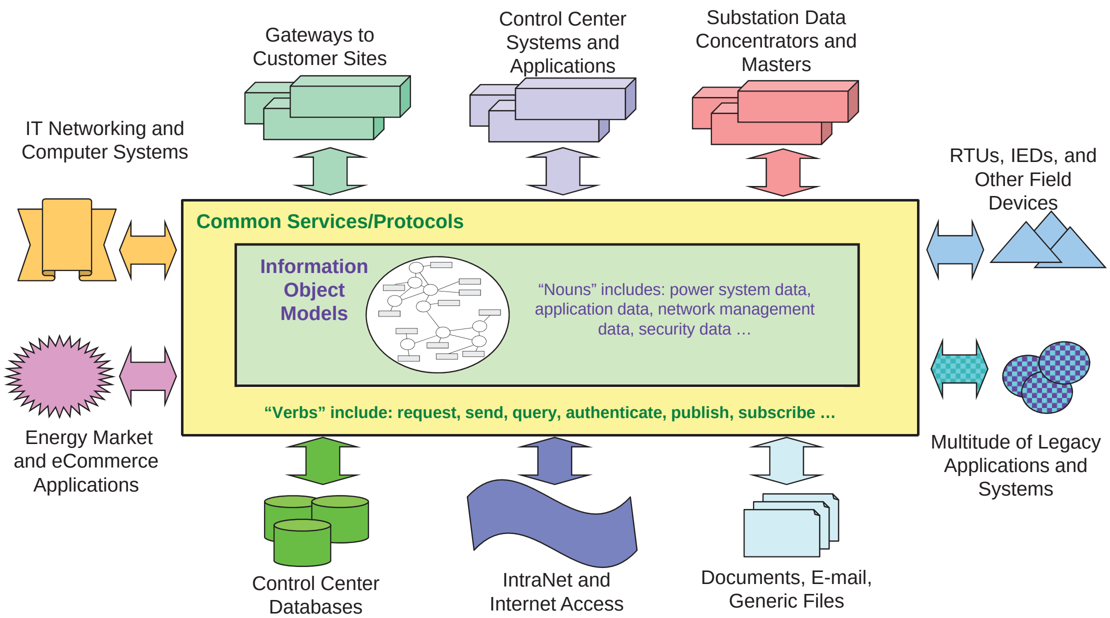


A "one-off" point to point link will always be cheaper if the cost to integrate future applications is ignored.

The Result of Justification One App at at Time

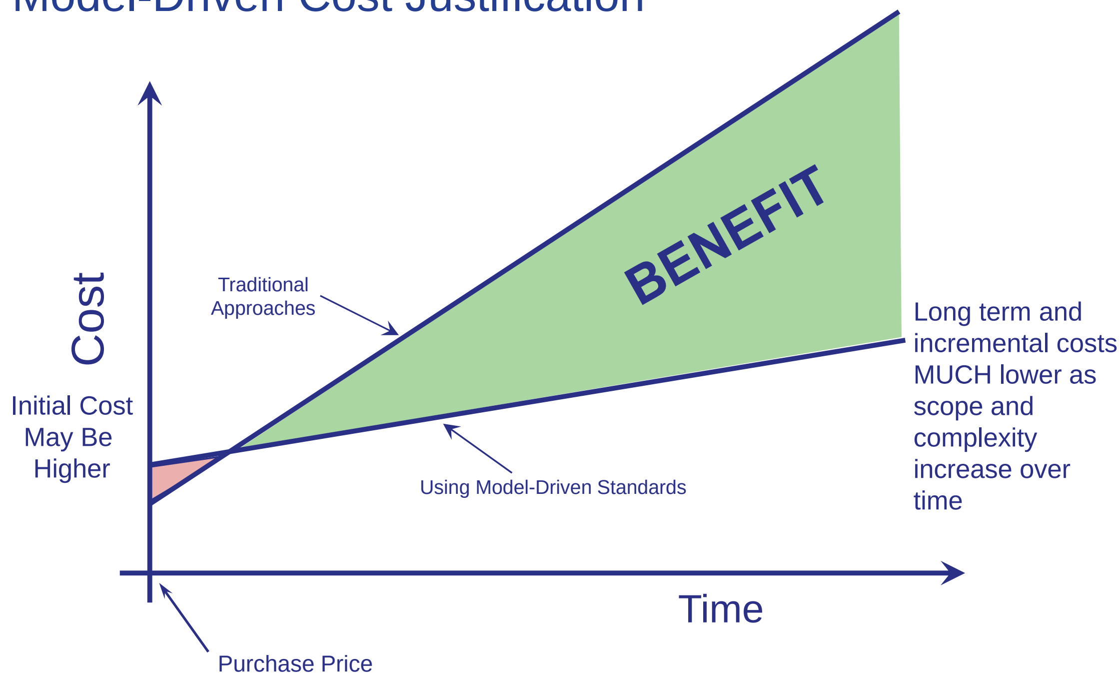


Model Driven Integration Addresses Cost, Efficiency, and Complexity for the LONG RUN



IntelliGrid Architecture http://www.intelligrid.info

Model-Driven Cost Justification



A Cautionary Note

- Interoperability and Integration of applications is a path, not an end point.
- By the time we get to were we are going today, someone will have moved the goal.
- **If you don’t set out on the path, you will never make any progress.**

"Obstacles are those frightful things that appear when you take your eyes off your objective."

- Henry Ford

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Questions - Discussion

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Thank You

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