IEC 61850 Fundamentals

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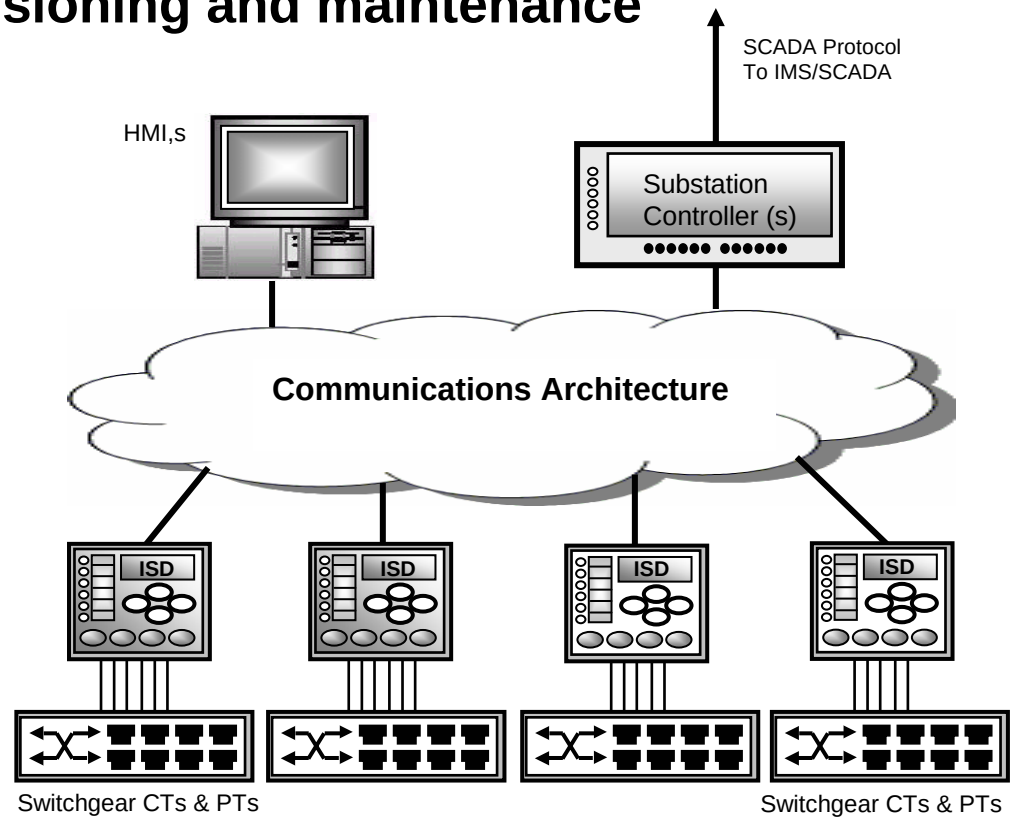
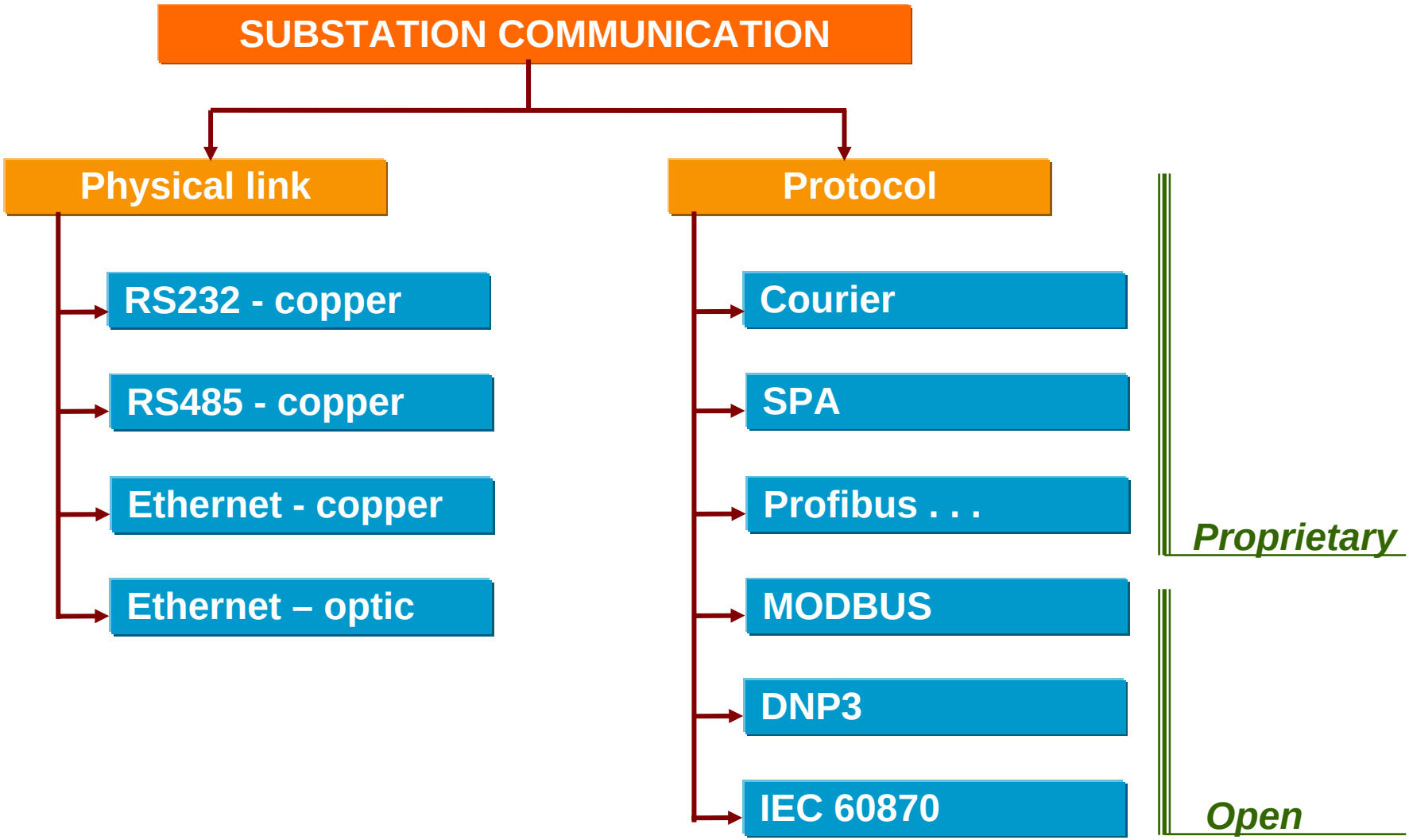
Communication in Substations

- Centralized monitoring and control
- With numerical relays (IEDs) substation automation has become more popular and easy to install
- Reduced hardwiring – saving time and effort on commissioning and maintenance



Communication in Substations



Existing Protocol Limitations

- High engineering costs
  - Each protocol had its own structure of representing data (approx. US $ 28 billion spent on application integration in 1998 – Forrester 1999.)
- Many protocols
  - Inter-operability was an issue.
  - Different levels of functionalities
- Use of proprietary protocol
  - limited use of multi-user products
- Each protocol supported

  Different standards followed in Europe and North America

Market Requirements

- Global Market
  - Needs a global standard
  - Means a broad range of philosophies
- Mixing of devices, at least with copper cables
- Cost reduction by
  - Competition
  - Intelligence (functions)

Market Requirements

- Cost reduction in
  - Investment
  - Operation
- Maintenance
- Open standard, especially for the future safe guard of investments

European historical perspective

- **TC57 - Power systems management and associated information exchange**
  - **IEC 60870-6** — **TASE 1 - ELCOM90**
TASE 2 - ICCP
  - **IEC 60870-5** — **101 telecontrol**
102 metering
103 protection and control
104 telecontrol over TCP

European historical perspective

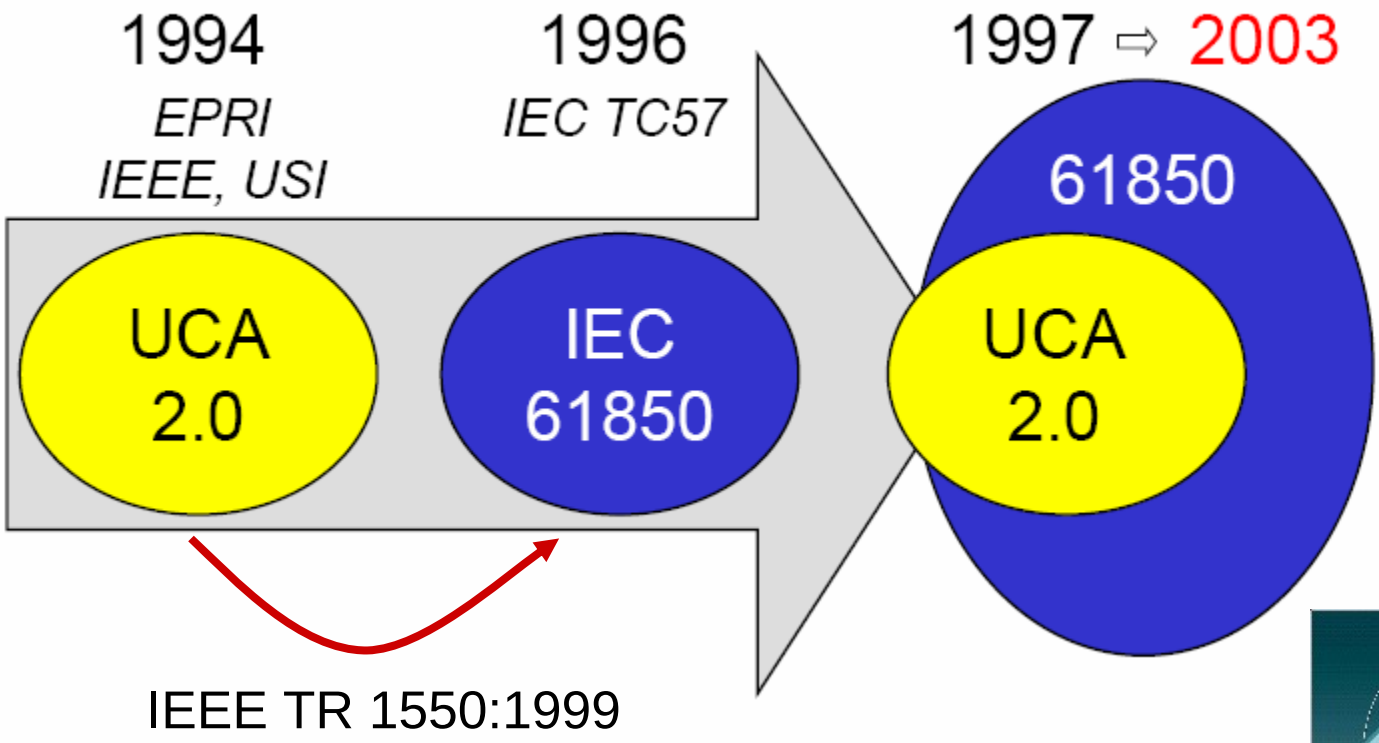
- 1994 AHWG created 2 New Work Item Proposals:
  - Short term solution
    - 103 = VDEW + Courier
  - Longer term solution
    - IEC 61850

American historical perspective

- **ANSI Market**
  - **MODBUS**
  - **MODBUS plus**
  - **DNP 3.0 level 2**

- **EPRI UCA 1.0 - TASE.2 (ICCP)**
  2.0 - Substation Initiative

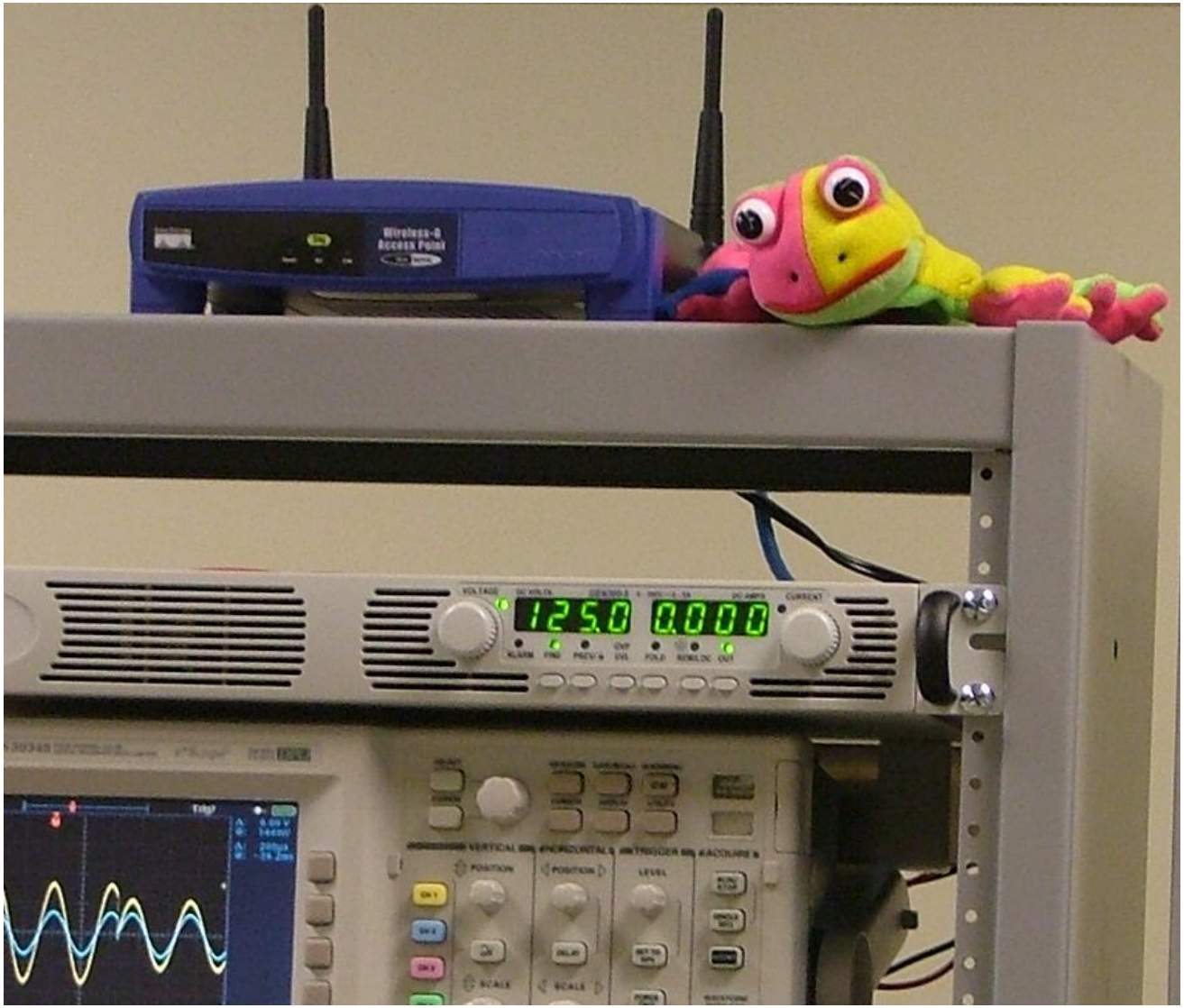
New Standards Emerge



UCA 2.0 is dead, forget it!

"UCA & 61850 for Dummies" – Douglas Proudfoot

Fred



Lucy

Working Group Members

Working Group Members

Working Group Members

Working Group Members

Working Group Members

Working Group Members

Introduction

IEC 61850

14 Parts

>1000 pages (English only !)

10 years of development

REAL SUBSTATION

Different vendors

Interoperability

Easy specification

Is it really *that* simple ?

IEC 61850 Standard - Organization

System Aspects

Part 1: Introduction and Overview

Part 2: Glossary

Part 3: General Requirements
Part 4: System and Project Management

Part 5: Comm. Requirements for Functions and Device Models

Configuration

Part 6: Configuration Language for electrical Substation IEDs

Data Models

Part 7-4: Compatible Logical Node Classes and Data Classes
Part 7-3: Common Data Classes

Abstract Communication Services

Part 7-2: Abstract Communication Services (ACSI)
Part 7-1: Principles and Models

Mapping to real Comm. Networks (SCSM)

Part 8-1: Mapping to MMS and to ISO/IEC 8802-3

Part 9-1: Sampled Values over Serial Unidirectional Multidrop Point-to-Point link

Part 9-2: Sampled values over ISO 8802-3

Testing

Part 10: Conformance Testing

IEC 61850: Basic applications and possible extensions

- Telecontrol of substations “sTCA” in discussion, IEC TC57 / Ad Hoc Working Group 07
- Addendum Power Quality, Monitoring under way, IEC 57/624/NP
- Product standard for switchgear equipment under way, IEC 62271-003
- Control and monitoring of wind power plants under way, IEC 61400-25
- Control and monitoring of distributed power stations under way, IEC 57/660/NP

IEC 61850: Basic applications and possible extensions

- Control and monitoring of hydroelectric power plants
  under way, IEC 57/661/NP
- Metering (EPRI, IEEE), Gas, Water
  in discussion
- Several other WG within:
  - IEEE PSRC H5: Setting, etc.
  - UCA International: Testing, etc.
  - CIGRE B5.11: Use of IEC 61850 in substation, etc.
  - DKE/VDN (Germany): Recommendations

IEC 61850 - in brief

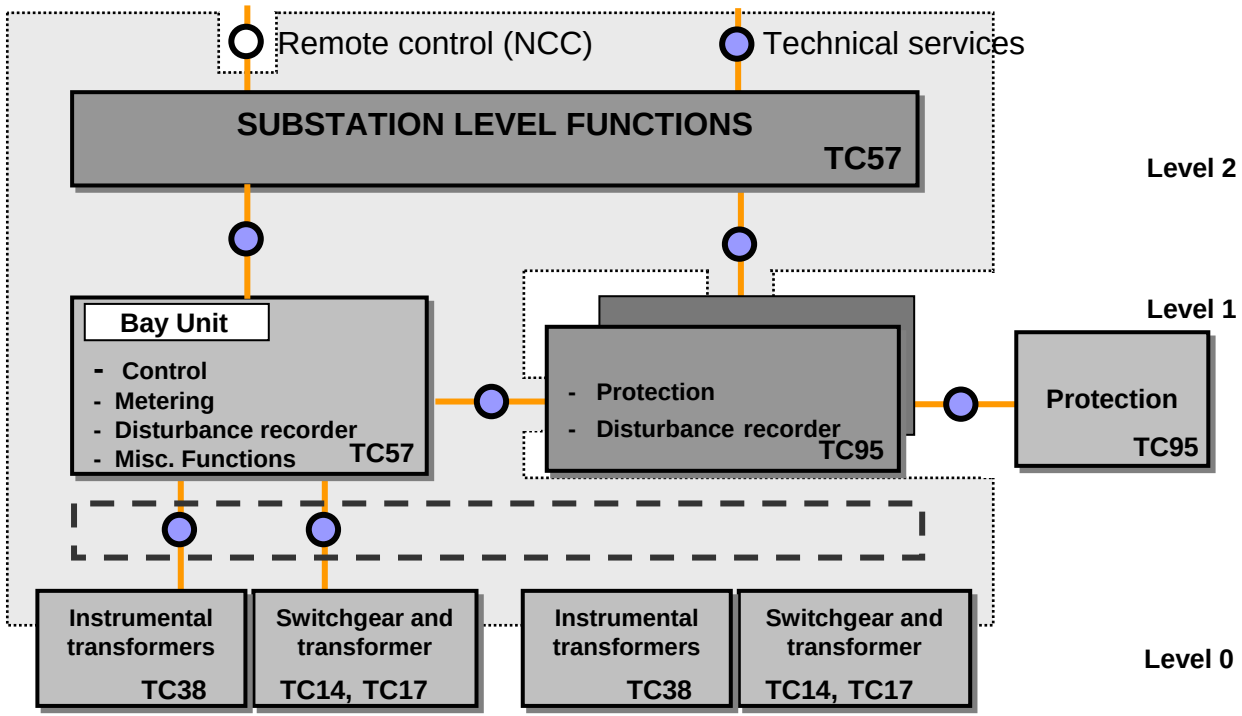
- Not just another bus system…
- Goes far beyond almost all other communication standards
- It extends the way automation devices "work together"
- Defines WHAT to communicate and HOW to communicate
- Everything has a name
- Configuration language for devices and substations

IEC 61850 - in brief

- Selects communication protocols
- Applicable in substations and many other domains
  - Wind power
  - Distributed Energy Resources
  - Hydro

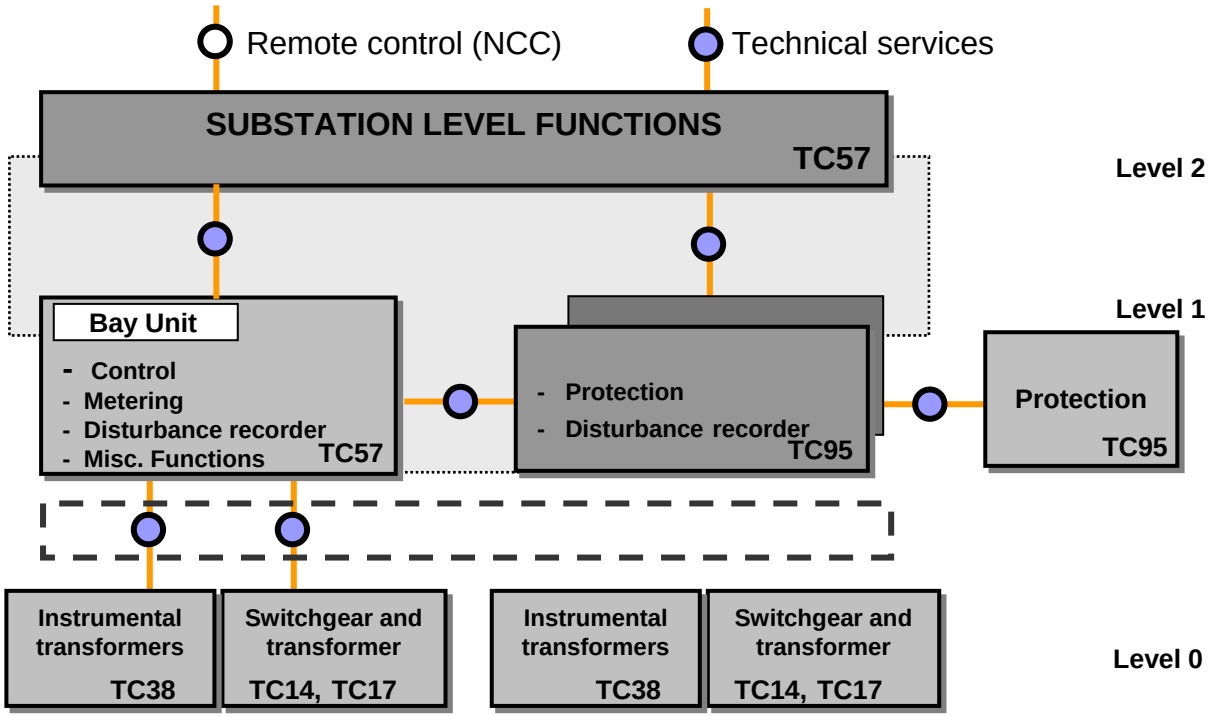
IEC 61850 - Scope

WG10: Functional Architecture and General Requirements



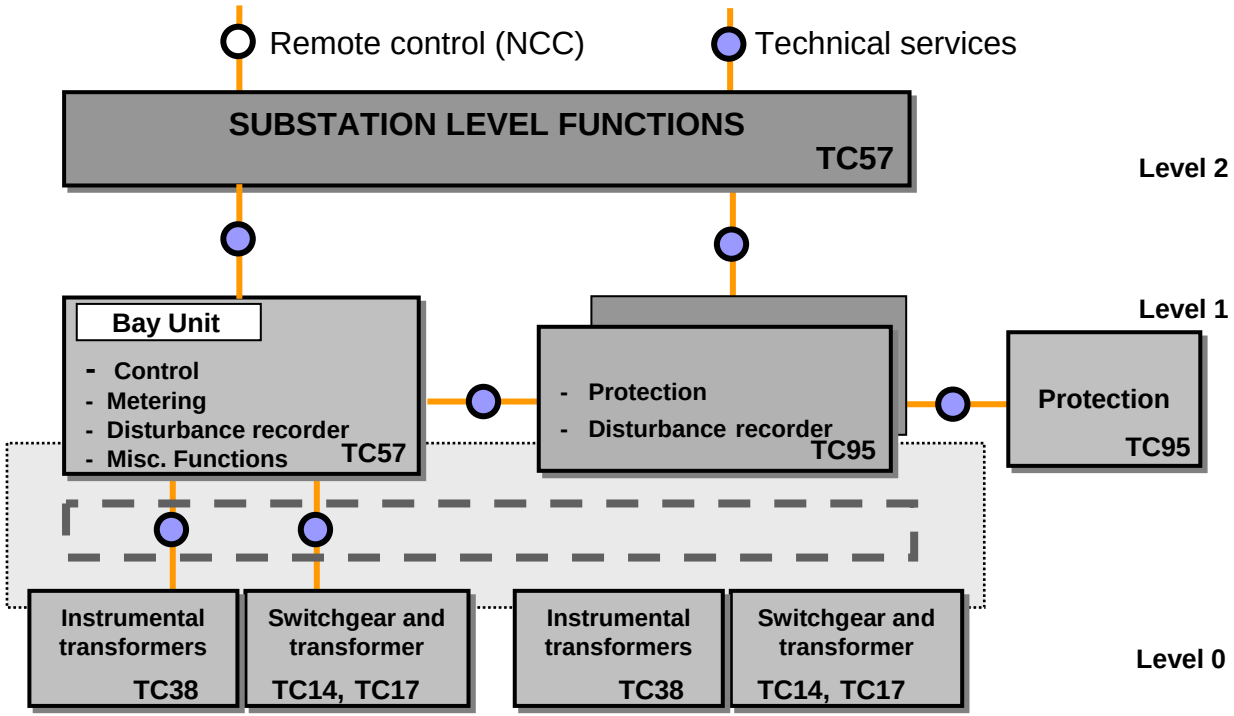
Station Bus

- ***WG11: Communication within and between Unit and Station levels***



Process Bus

- ***WG12: Communication within and between Process and Unit levels***



IEC 61850 Standard

- Uses the strengths of the OSI 7 layer communication model
- Station bus
  - Communication between IED and master stations
  - Data polled by Master from IED (Buffered or un-buffered)
  - Inter IED data exchange through multi-cast GOOSE messages
- Process bus
  - Communication between plant equipment and IEDs (switchgear, Instrument transformers)
  - Exchange of sampled values
- Bus separation is becoming less distinct

Standardized data models for all applications

Requirements of New Standard

- **The goal of the IEC 61850 standard is to ensure:**

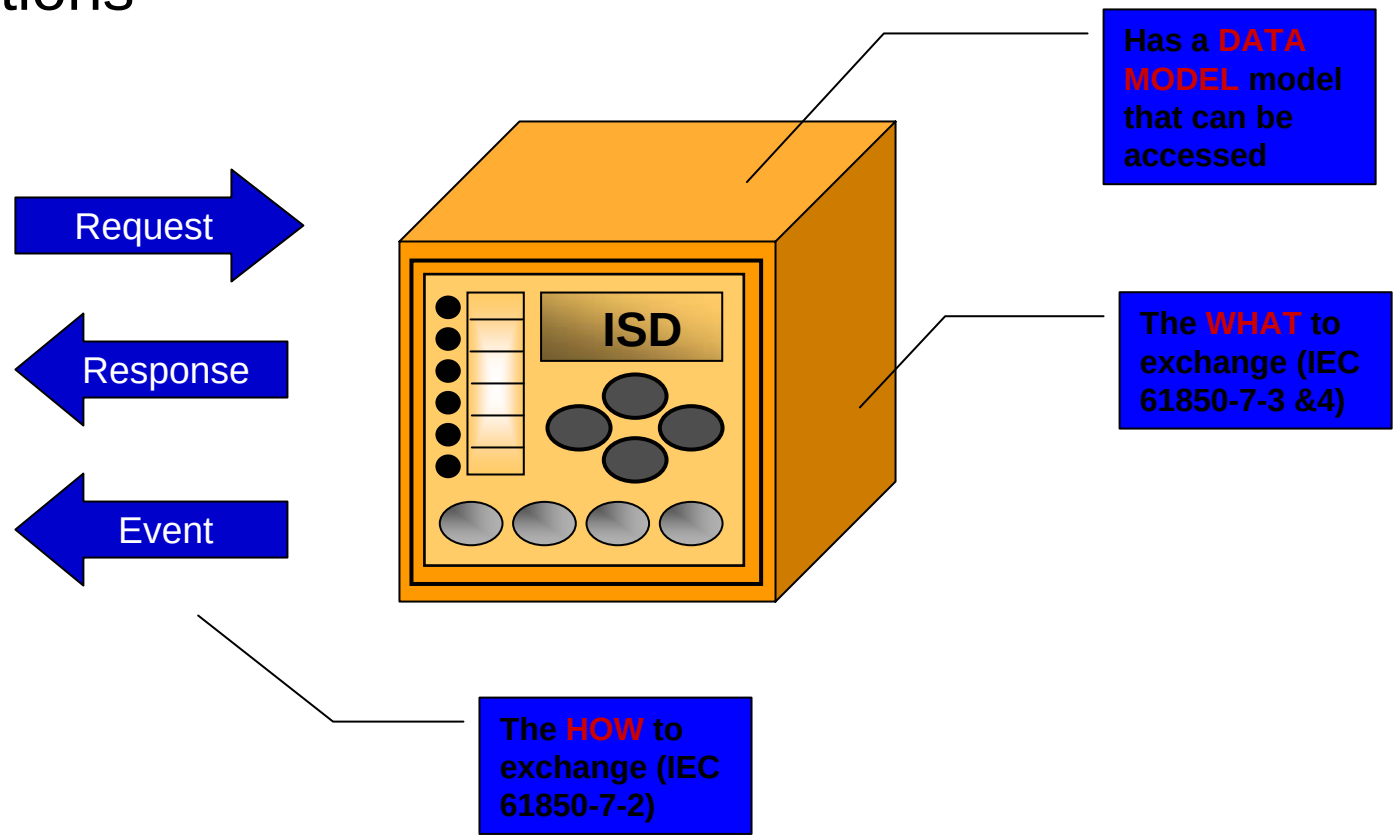
Interoperability: The ability for IED's from one or several manufacturer to exchange information and use the information for the their own functions.

Free Configuration: **The** support of different philosophies and ability for free allocation of functions, i.e. it will work equally well for centralized (RTU like) or decentralized (SCS like) systems.

Long Term Stability: The standard shall be future proof, i.e. it must be able to follow the progress in communication technology as well as evolving system requirements.

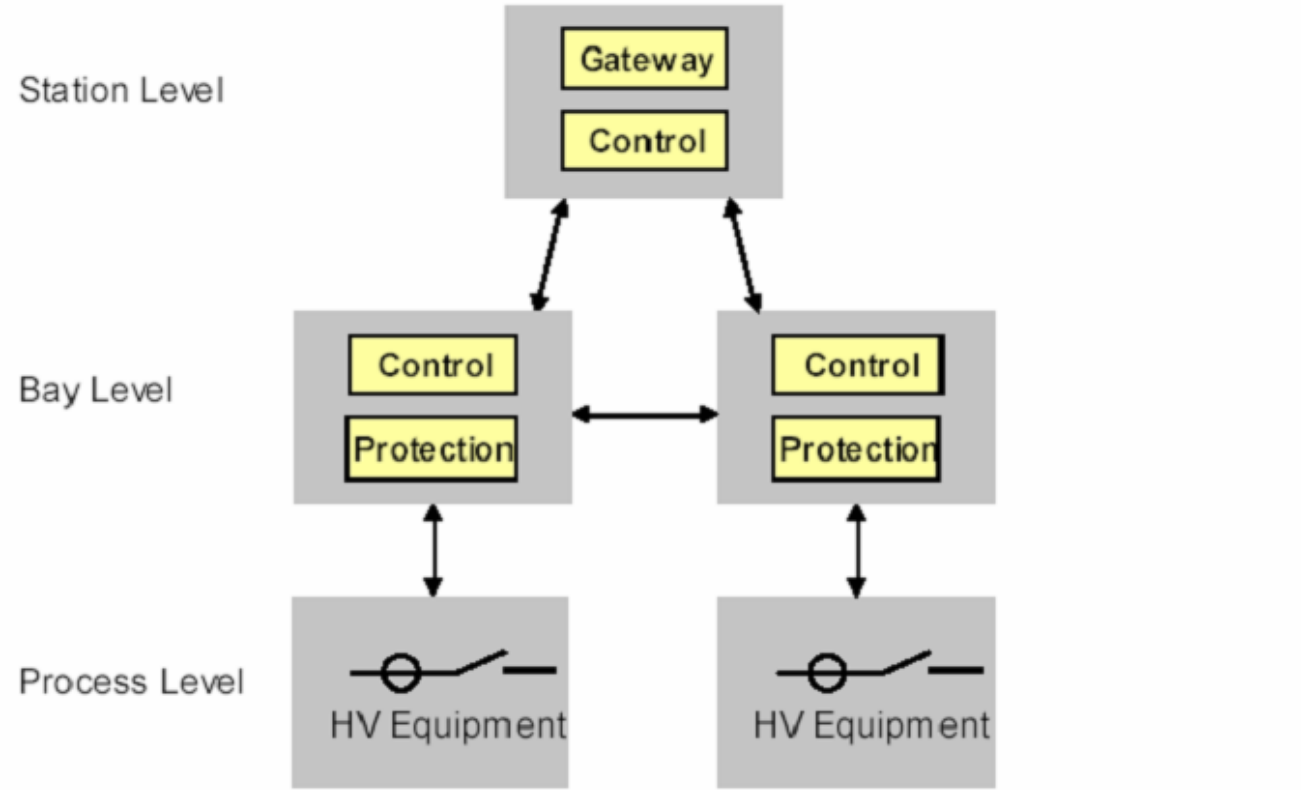
Interoperability

- Ability of two or more IEDs from the same vendor, or from different vendors, to exchange information and use that information for correct execution of specified functions



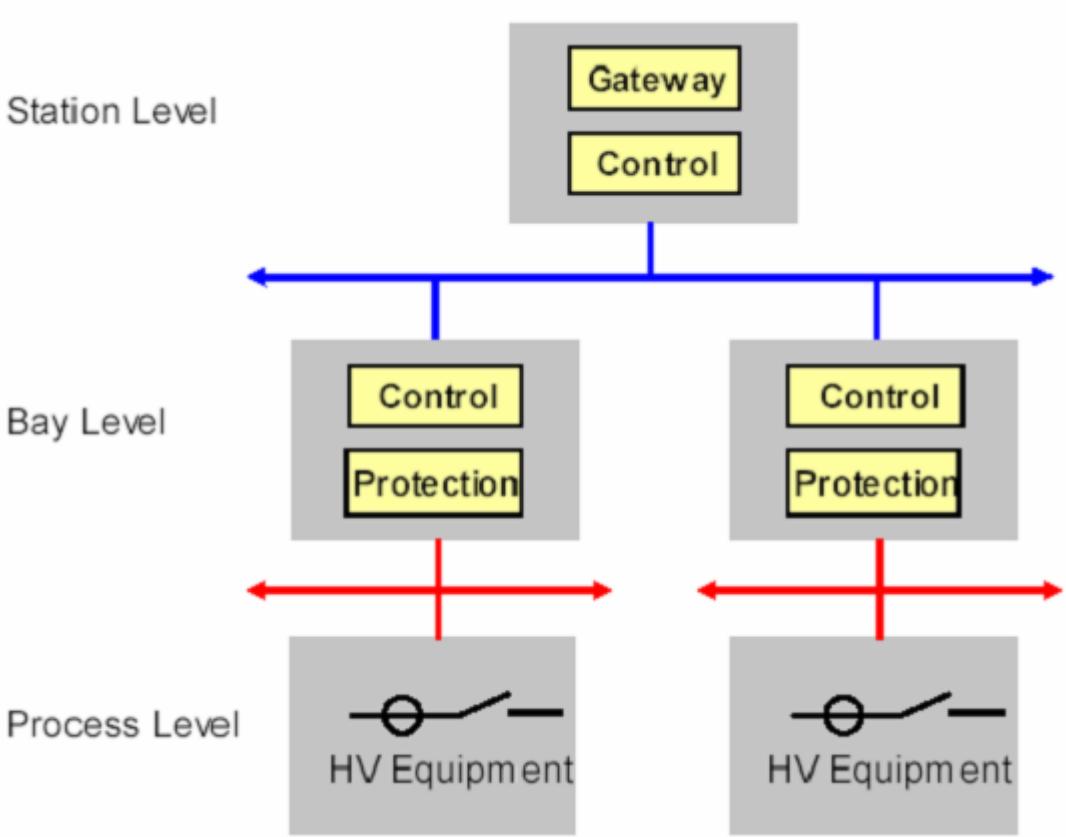
Free Configuration of communication

- **Hardwired & point to point links**



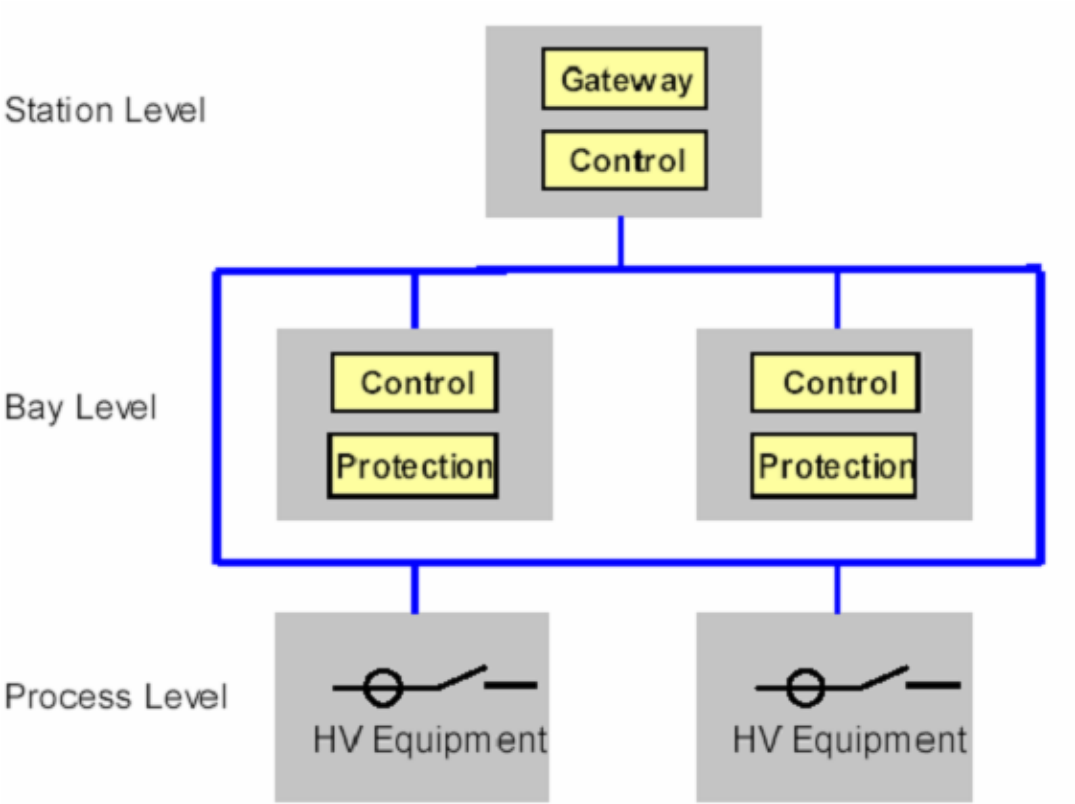
Free Configuration of communication

- **Separate Station and Process bus networks**

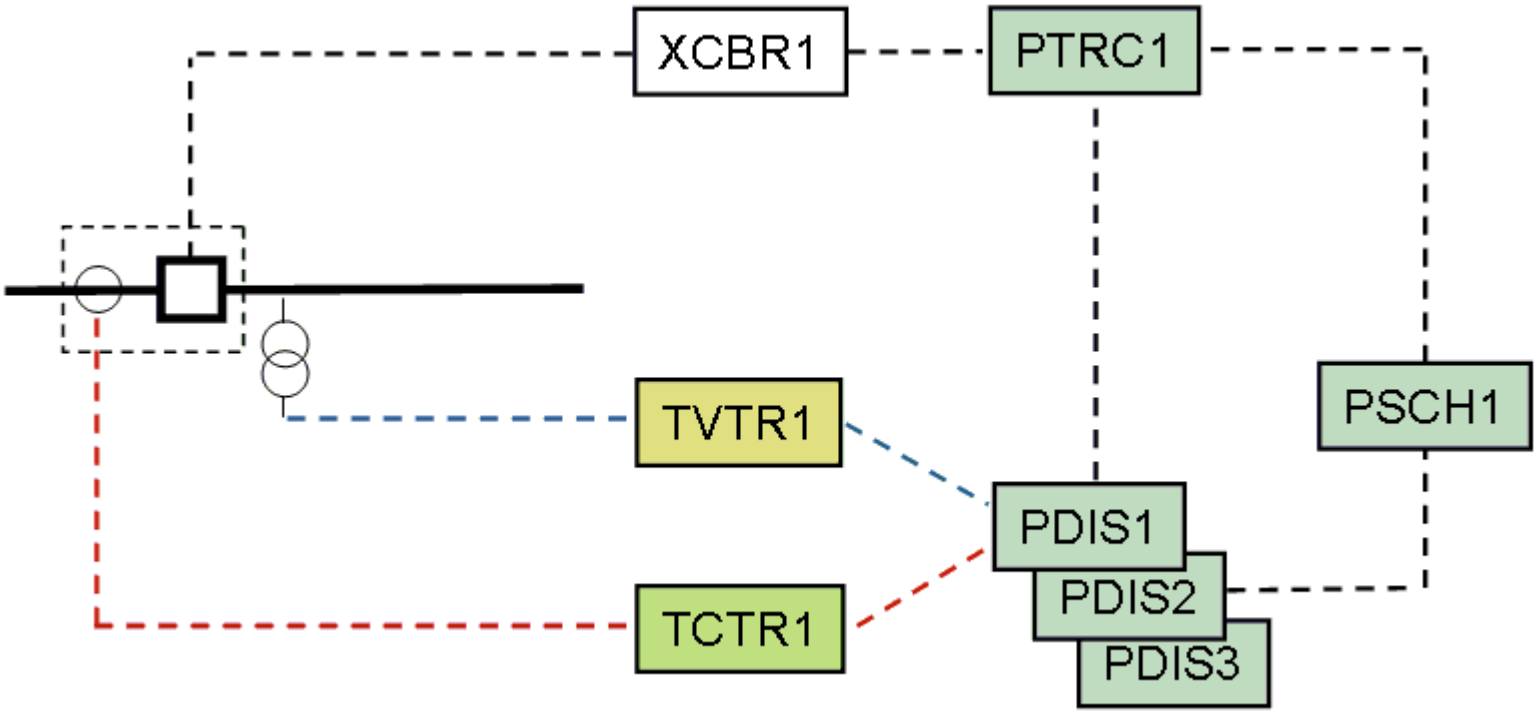


Free Configuration of communication

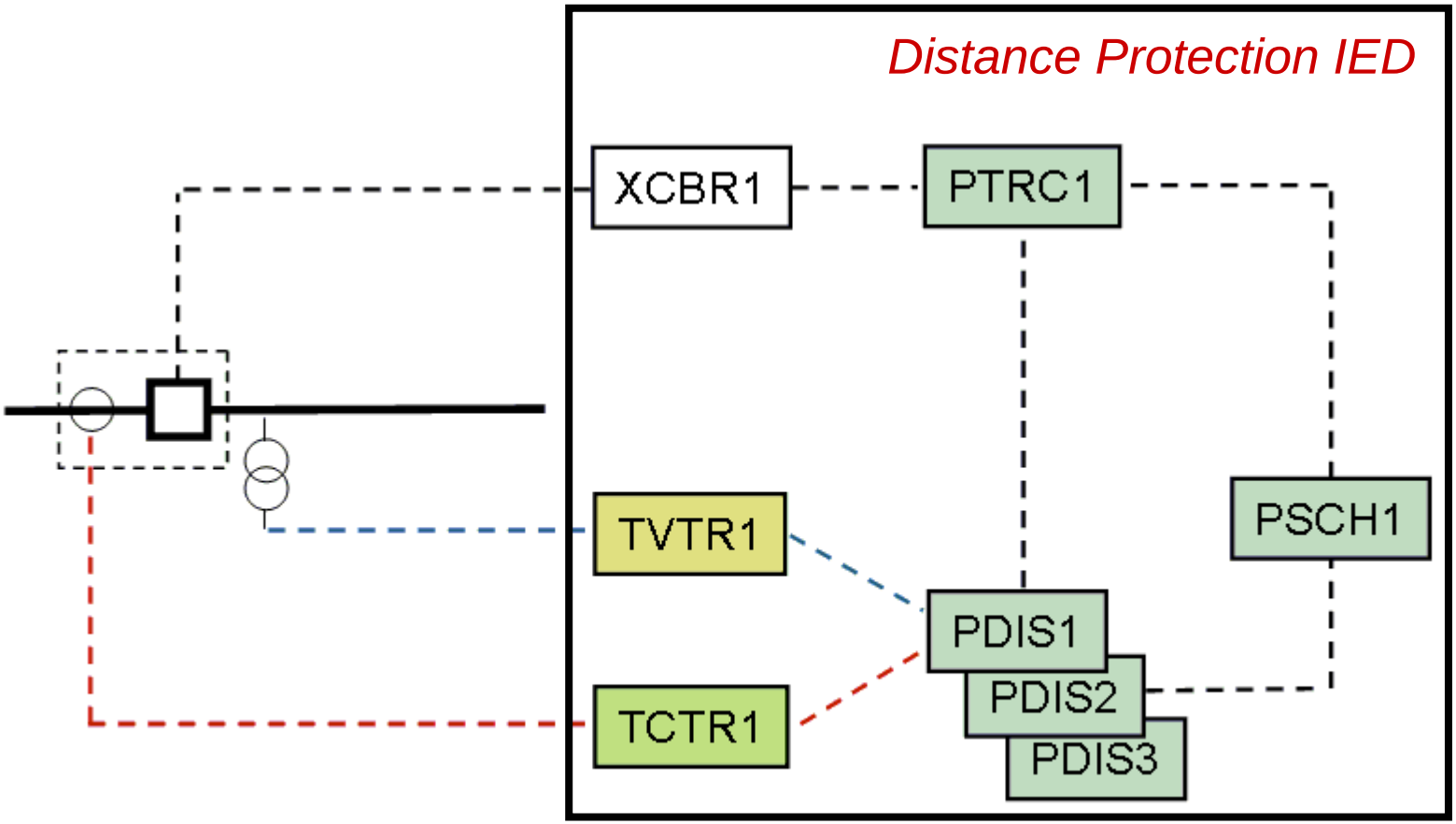
- **Single substation bus network**



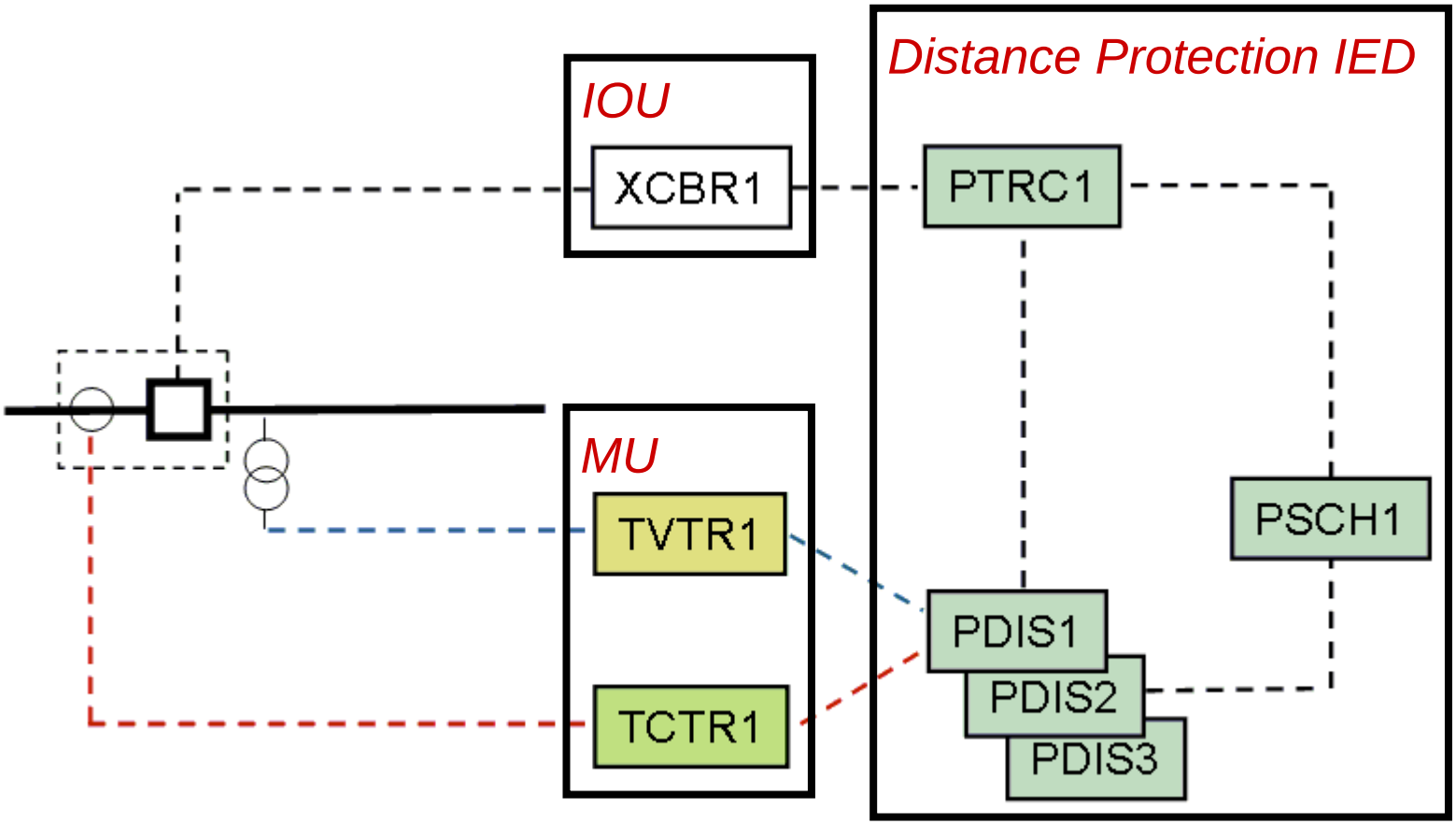
Distance Protection Function Model



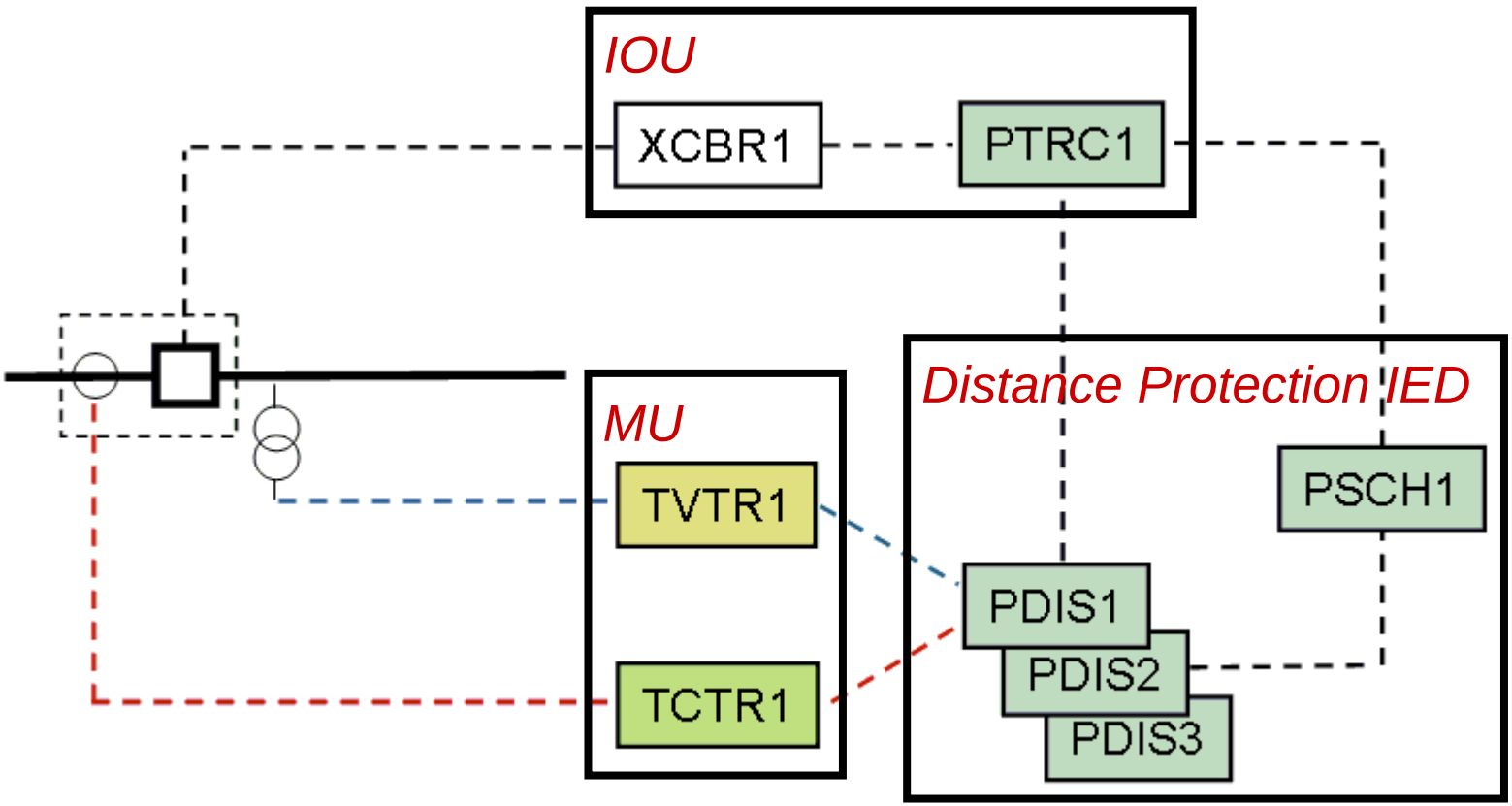
Distance Protection Functions Distribution



Distance Protection Functions Distribution

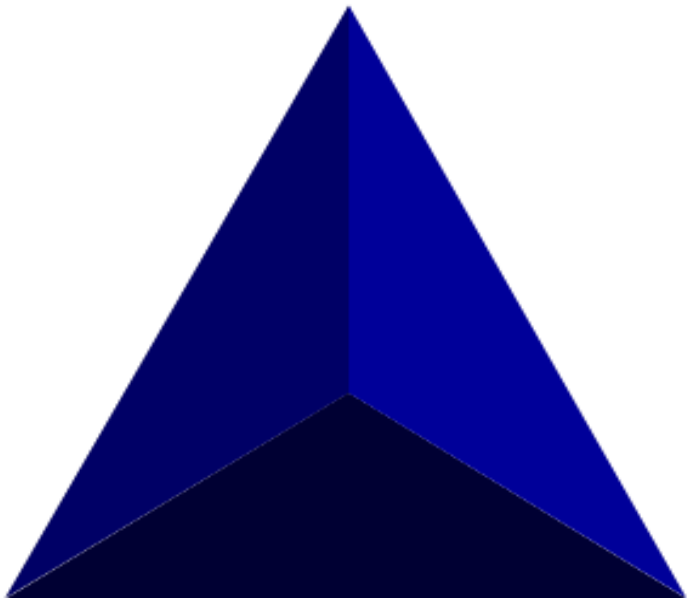


Distance Protection Functions Distribution



Generic Communication Model

Data Access Model



Semantics **Services**

Modeling Approach

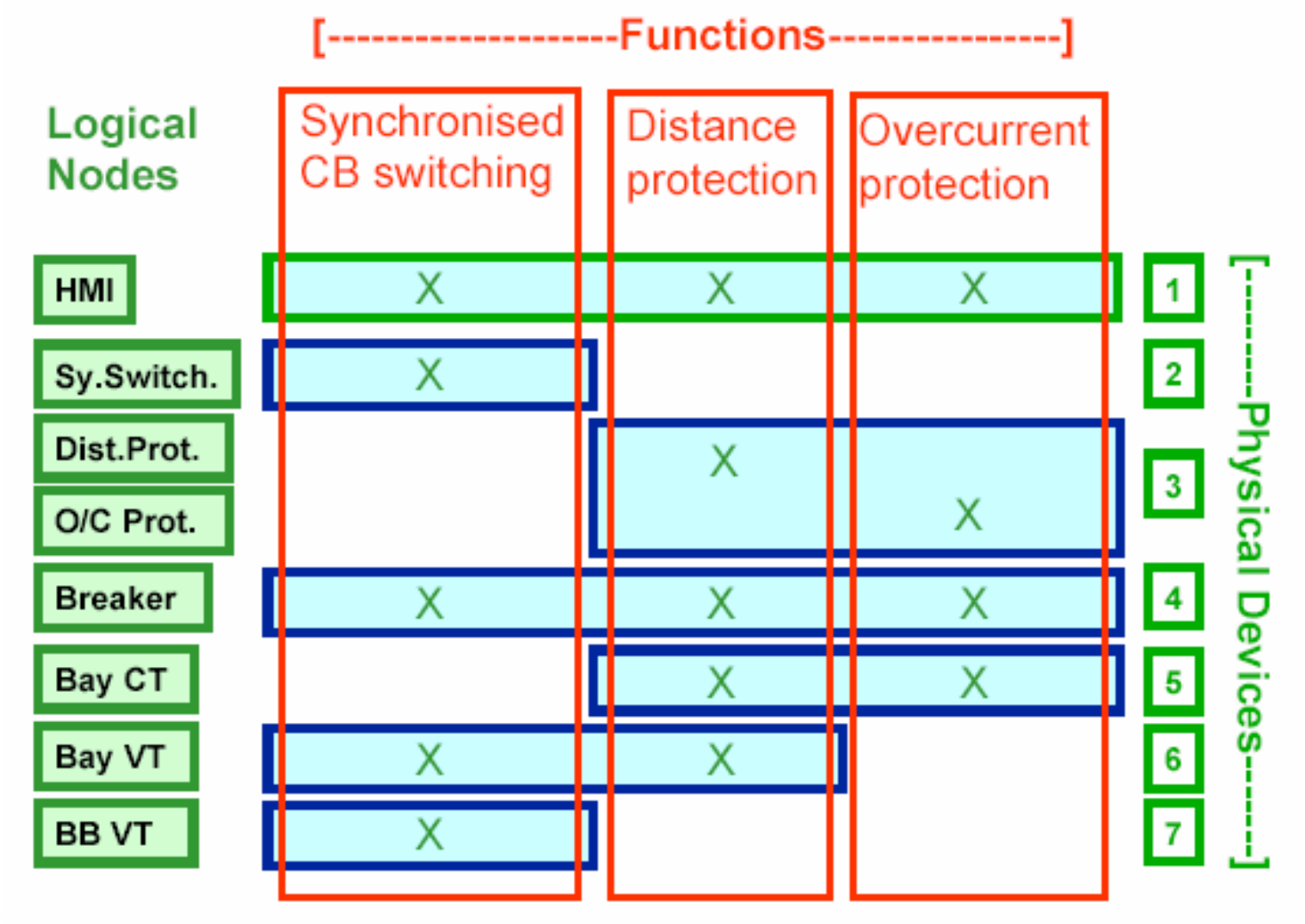
- **Functional Decomposition**
  - **Used to understand the logical relationships between components of a distributed function and is presented in terms of logical nodes that describe the functions, sub-functions and functional interfaces**
- **Data Flow**
  - **Used to understand the communication interfaces that must support the exchange of information between distributed functional components and the functional performance requirements**

Modeling Approach

- **Information Modeling**
  - **Used to define the abstract syntax and semantics of the information exchanged and is presented in terms of data object classes and types, attributes, abstract object methods (services) and their relationships**

- **Object oriented communications organise the data by function to simplify distributed applications**
- **Standardized object models allow for application interoperability**
- **Self-description and Meta-Data allows for online validation**
- **Focus is shifting from data acquisition to Data Management**

Functions, Logical Nodes and Physical Devices



Data Communication using IEC 61850

- **Logical Nodes – 92 Logical Node Classes**

Logical node groups	Number of logical nodes
System logical nodes	3
Protection functions	28
Protection related functions	10
Supervisory control	5
Generic references	3
Interfacing and archiving	4
Automatic control	4
Metering and measurement	8
Sensors and monitoring	4
Switchgear	2
Instrument transformer	2
Power transformer	4
Further power system equipment	15
Total number of logical nodes	92

PDIR	Directional element
PHAR	Harmonic restraint
PSCH	Protection Scheme
PTEF	Transient Earth Fault
PZSU	Zero speed or underspeed
PDIS	Distance protection
PVPH	Volts per Hz relay
PTUV	Undervoltage
PDOP	Directional over power
…more	

MMXU	Measuring (Measurand unit)
MMTR	Metering
MSQI	Sequence and Imbalance
MHAI	Harmonics and Inter-harmonics
MDIF	Differential Measurements
…more	

XCBR	Circuit Breaker
XSWI	Circuit Switch

"IEC61850-7-1 Standard"

Data Communication using IEC 61850

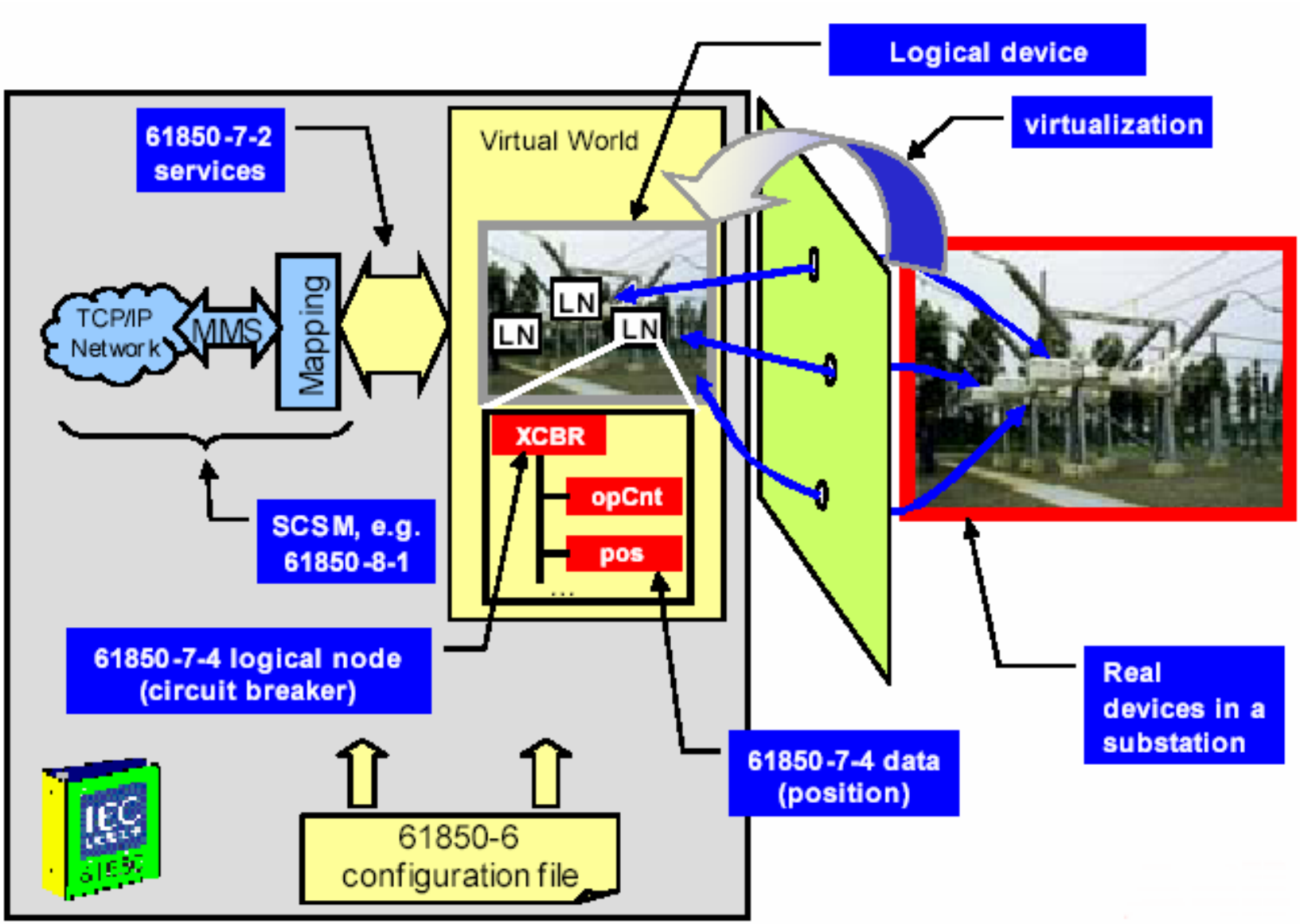
- **Logical Groupings – 13 different groups**

Group Indicator	Logical node groups
A	Automatic Control
C	Supervisory control
G	Generic Function References
I	Interfacing and Archiving
L	System Logical Nodes
M	Metering and Measurement
P	Protection Functions
R	Protection Related Functions
S [a)]	Sensors, Monitoring
T [a)]	Instrument Transformer
X [a)]	Switchgear
Y [a)]	Power Transformer and Related Functions
Z [a)]	Further (power system) Equipment

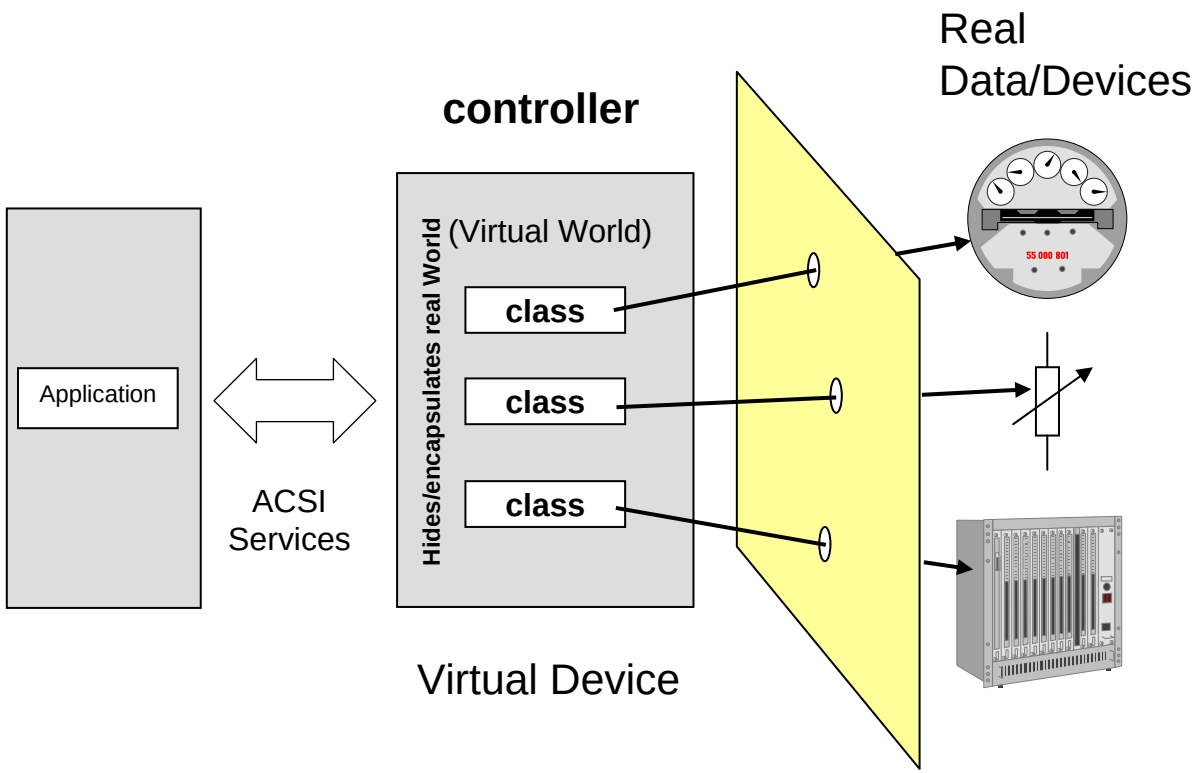
[a)] LNs of this group exist in dedicated IEDs if a process bus is used. Without a process bus, LNs of this group are the I/Os in the hardwired IED one level higher (for example in a bay unit) representing the external device by its inputs and outputs (process image – see Figure B.5 for example).

"IEC61850-7-4 Standard"

Virtualization

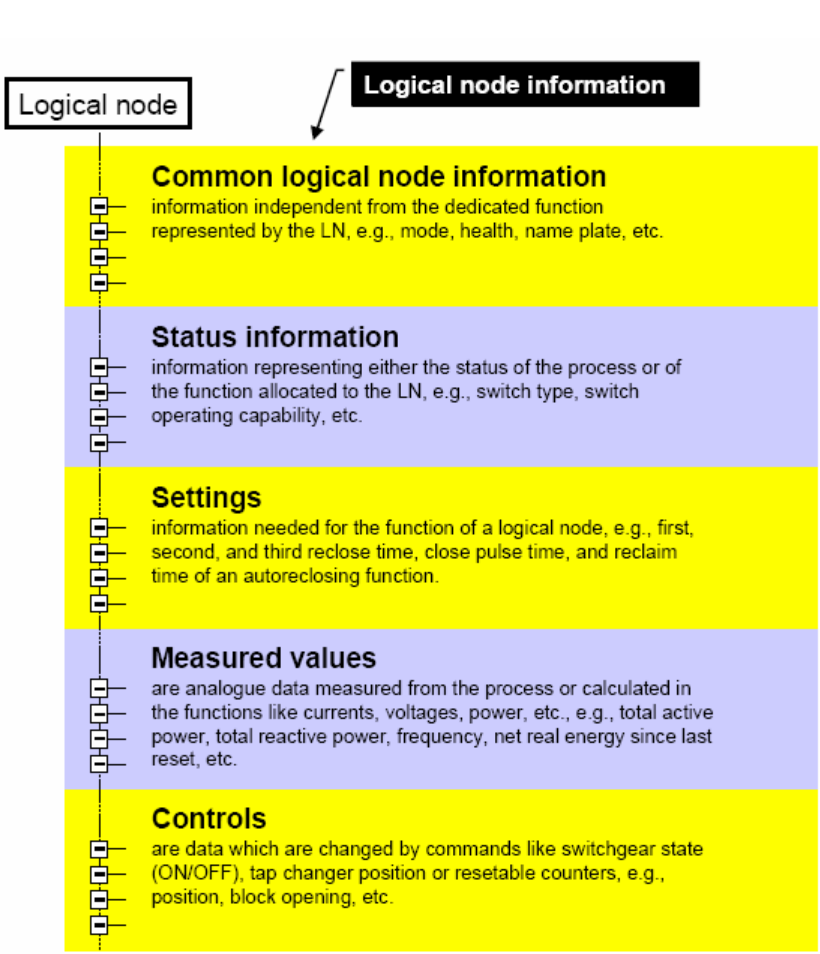


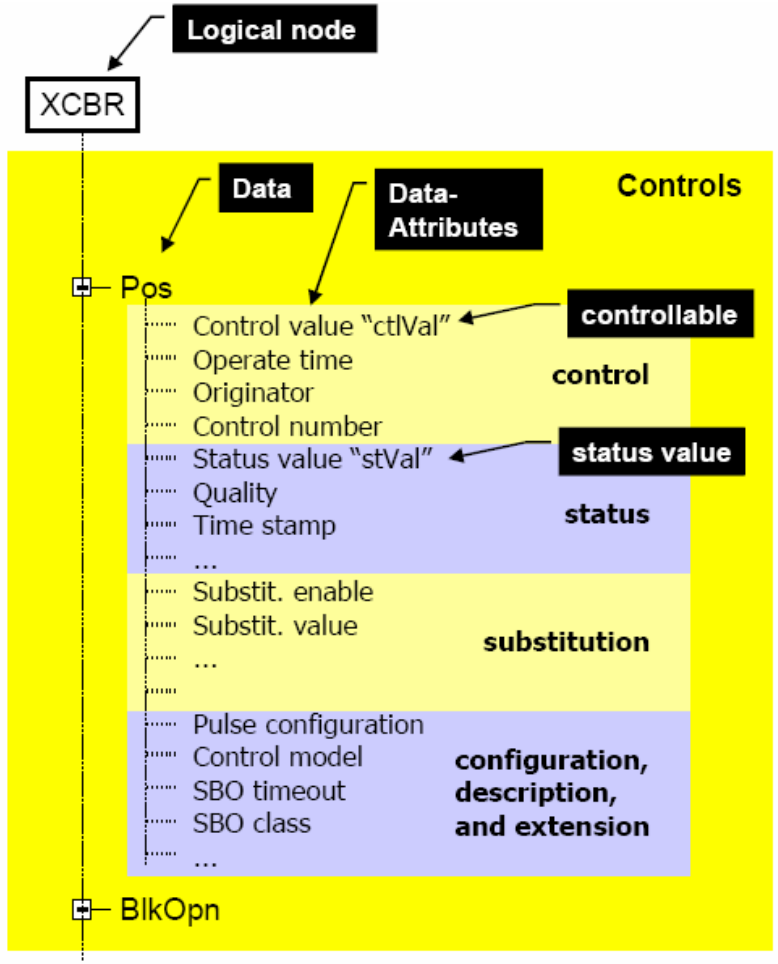
Virtualization



Data Communication using IEC 61850

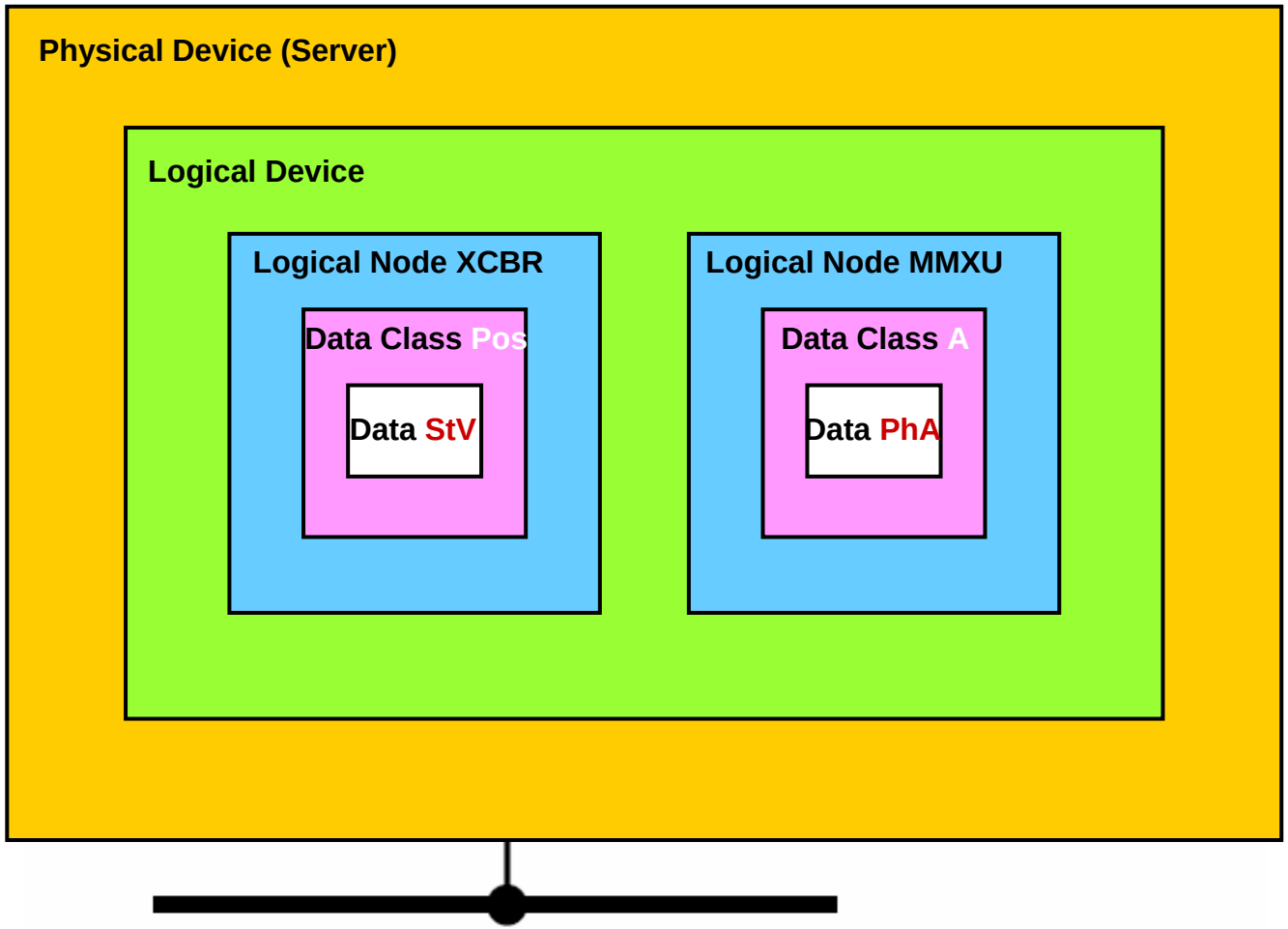
- **Data classes and example**



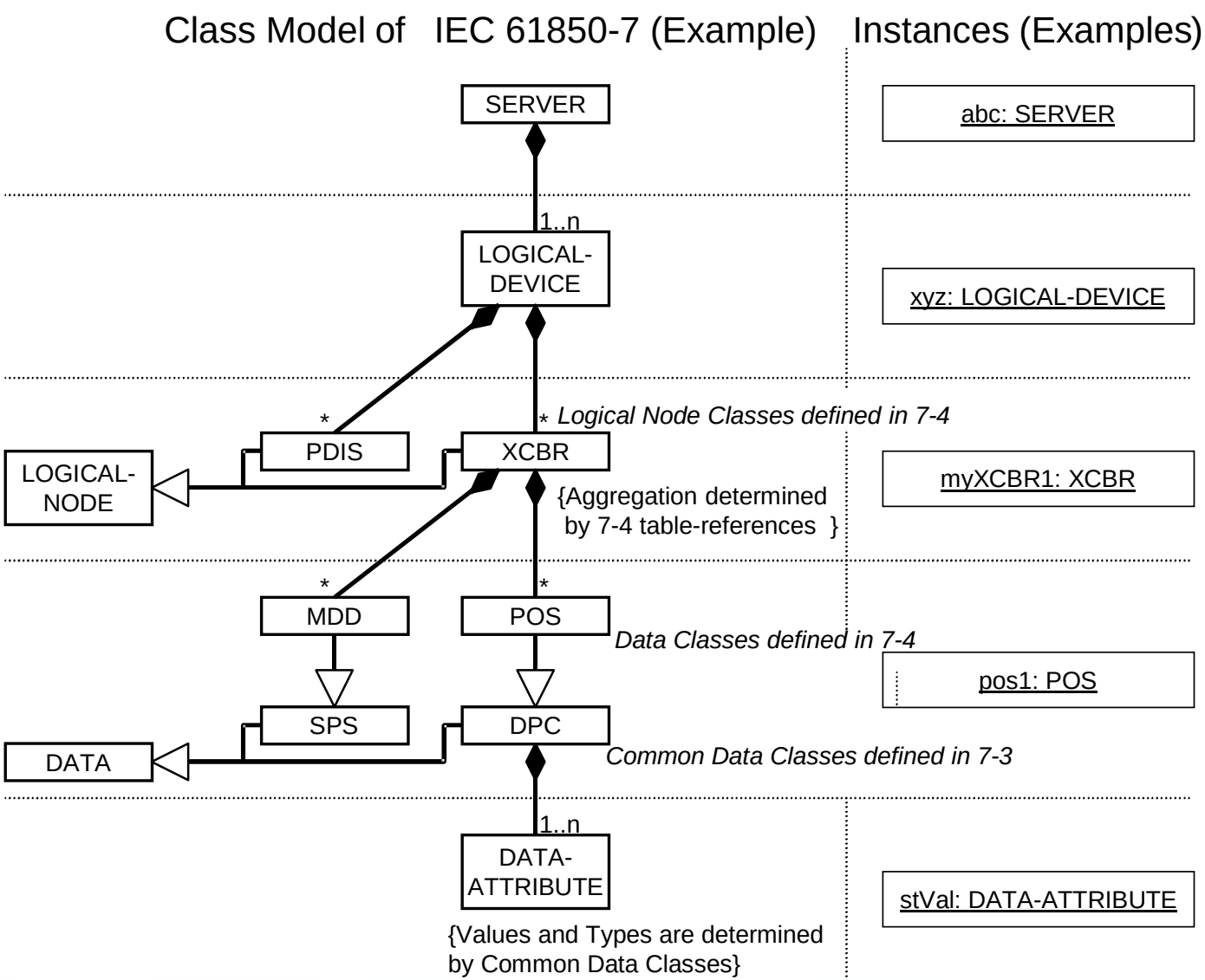


Data Communication using IEC 61850

- Logical groupings – Devices, nodes, classes and data.



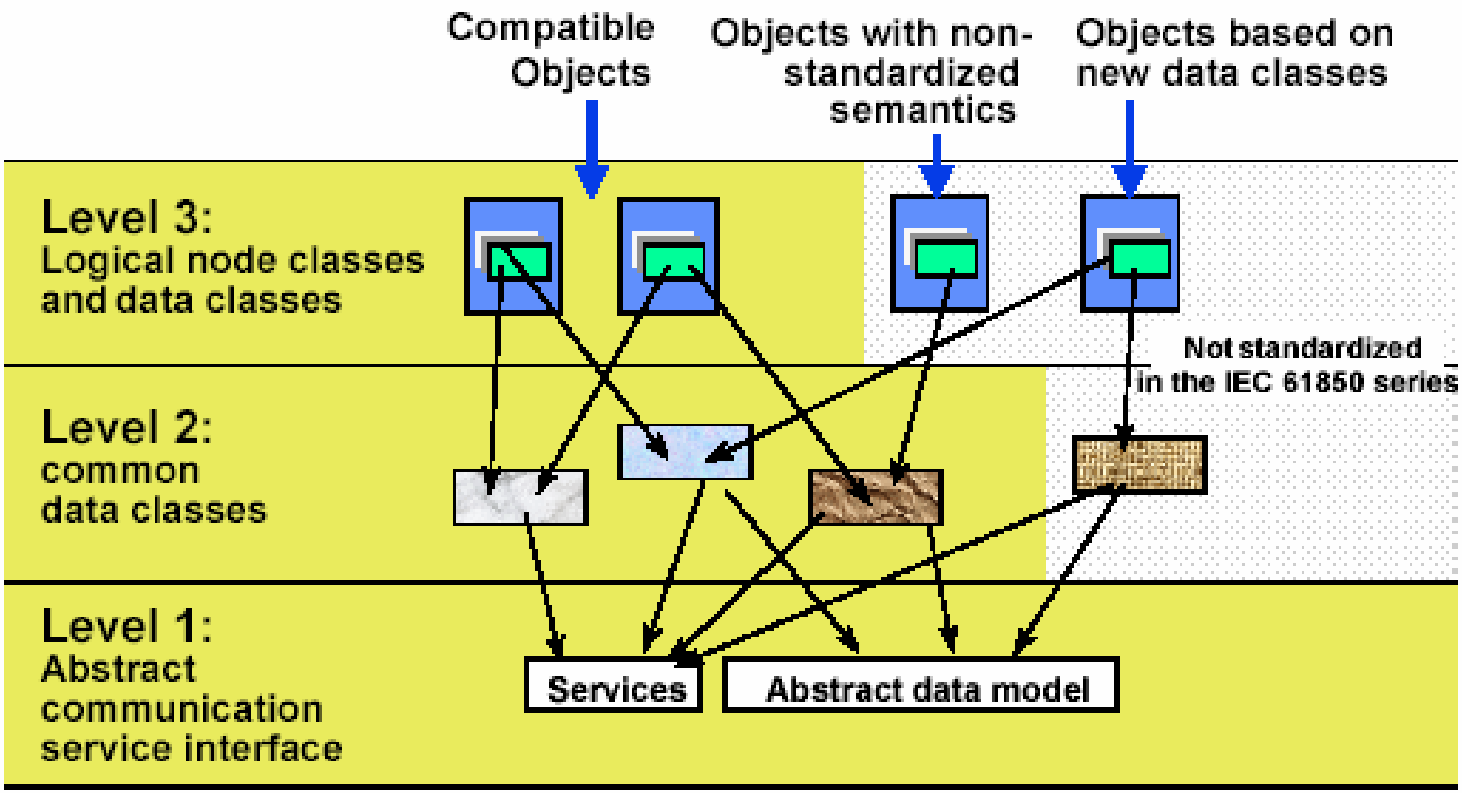
IEC 61850 Class Model



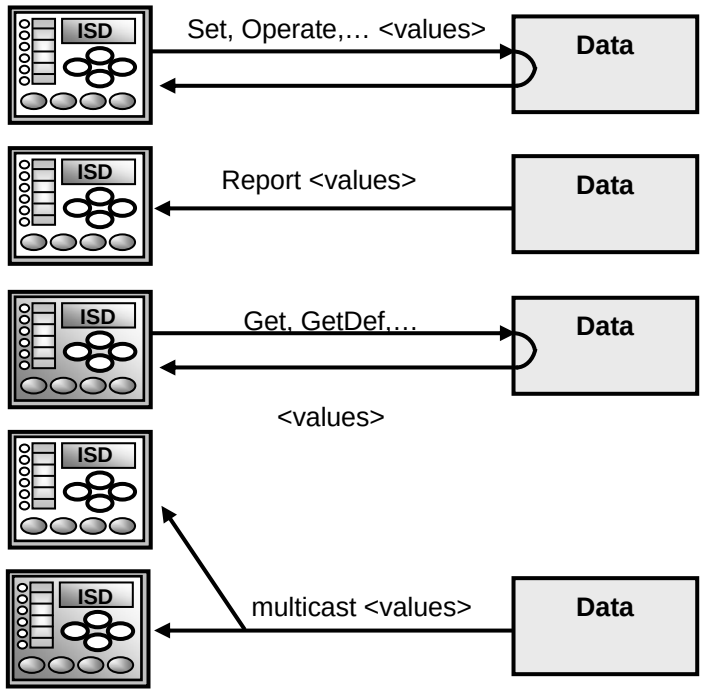
Self-describing Data

- A client can discover the device server's capabilities
- Comparable to the services of a web browser
- Used initially when defining the system configuration or during tuning/maintenance of the system

Modeling Approach - Standardized extensions



Information Flow - Services



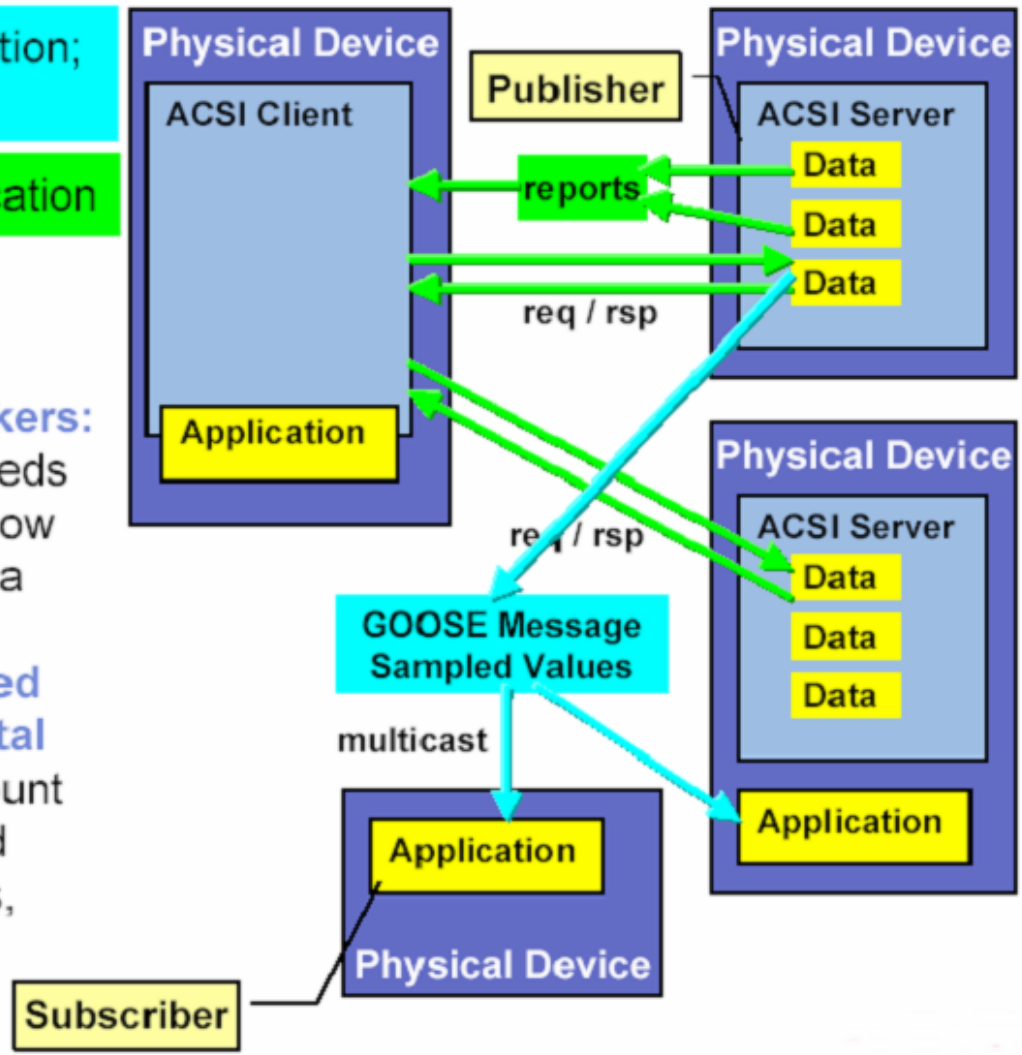
Communication Concepts

Peer to peer communication; time critical

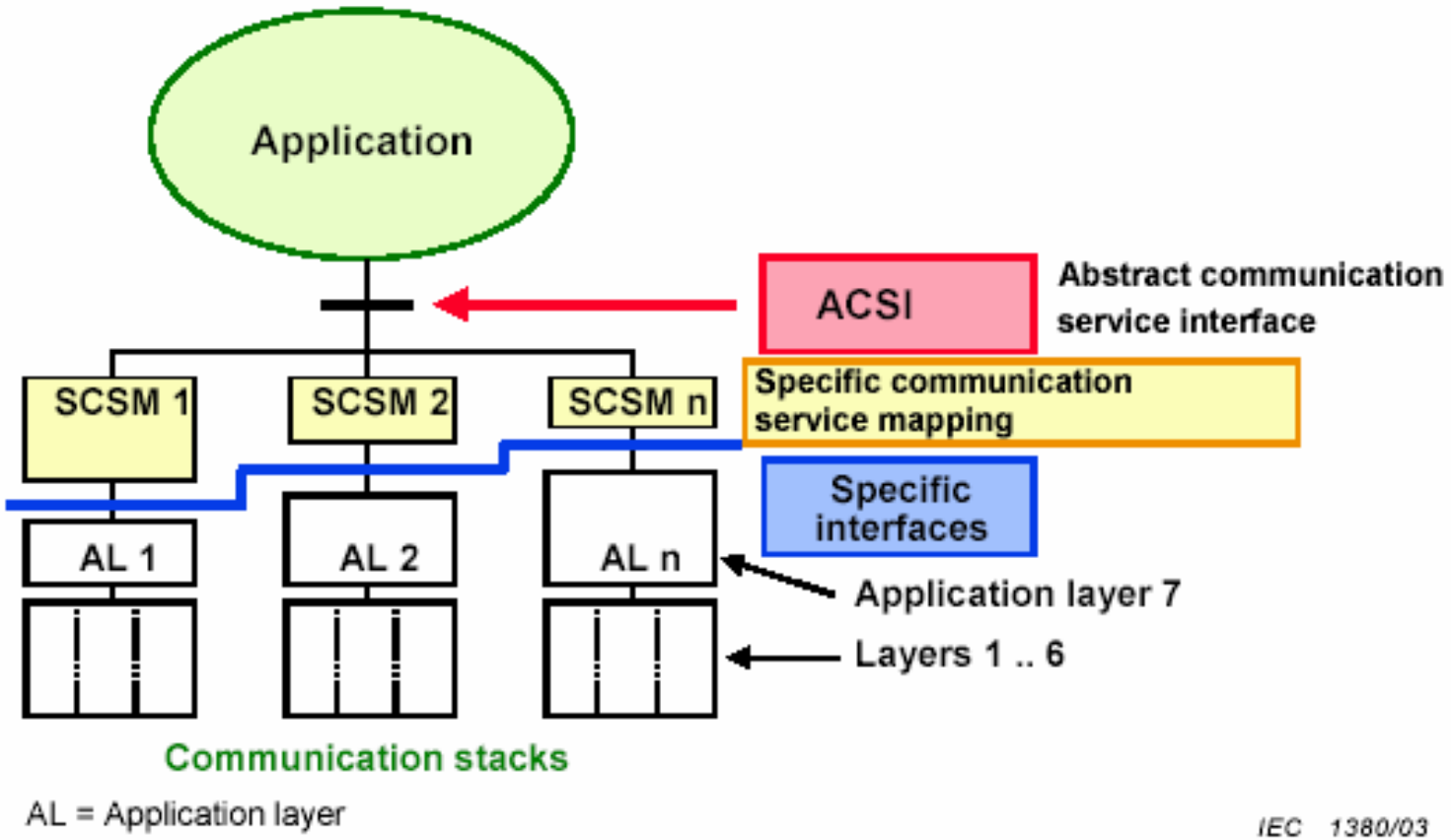
Client / Server communication

Applications of "peer-to-peer" communication

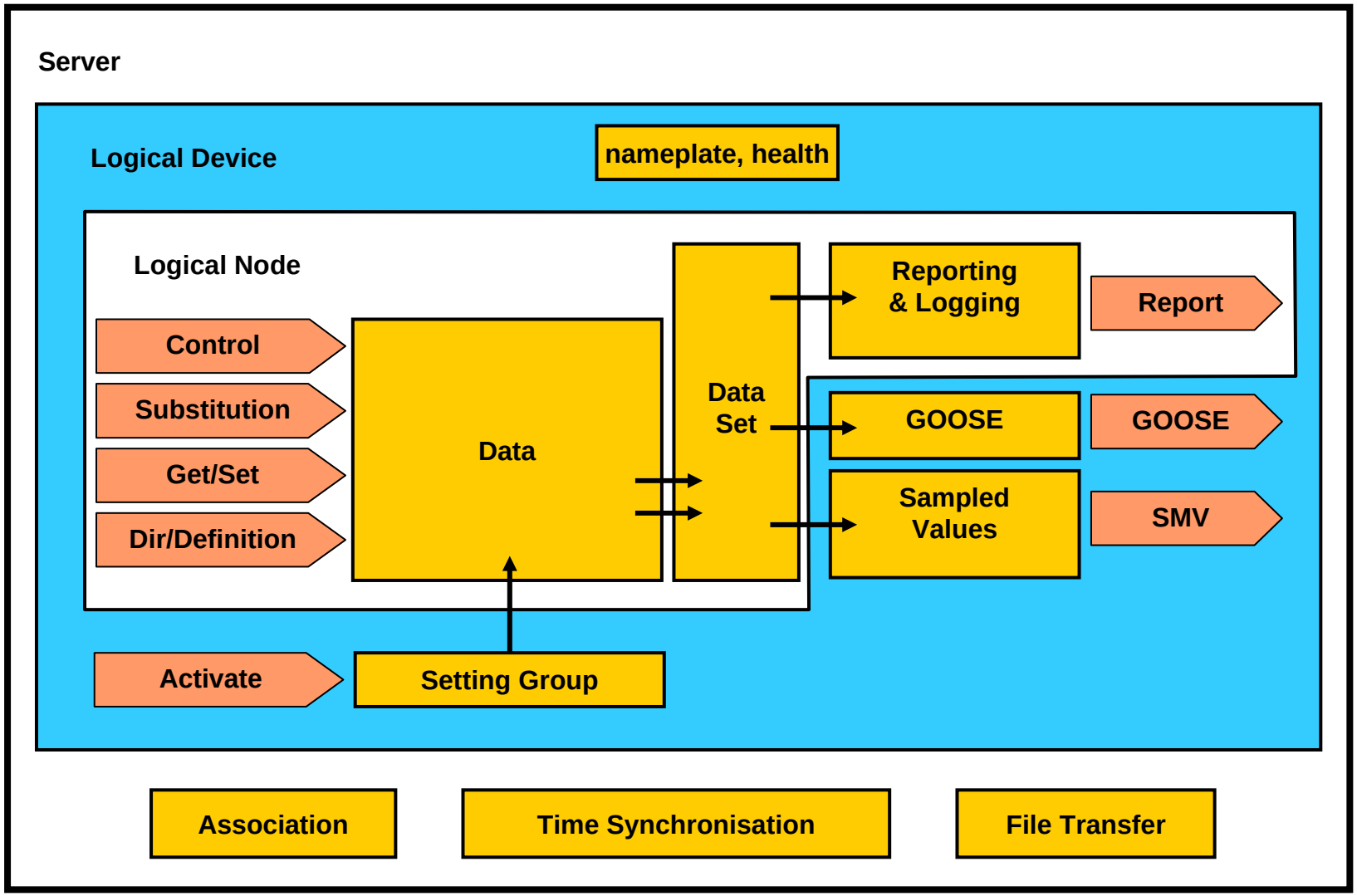
- tripping of circuit breakers: short information that needs to be transmitted with a low probability of loss within a few milliseconds
- transmission of sampled values from instrumental transformers: high amount of data, to be transmitted within a few milliseconds, loss of data needs to be detected



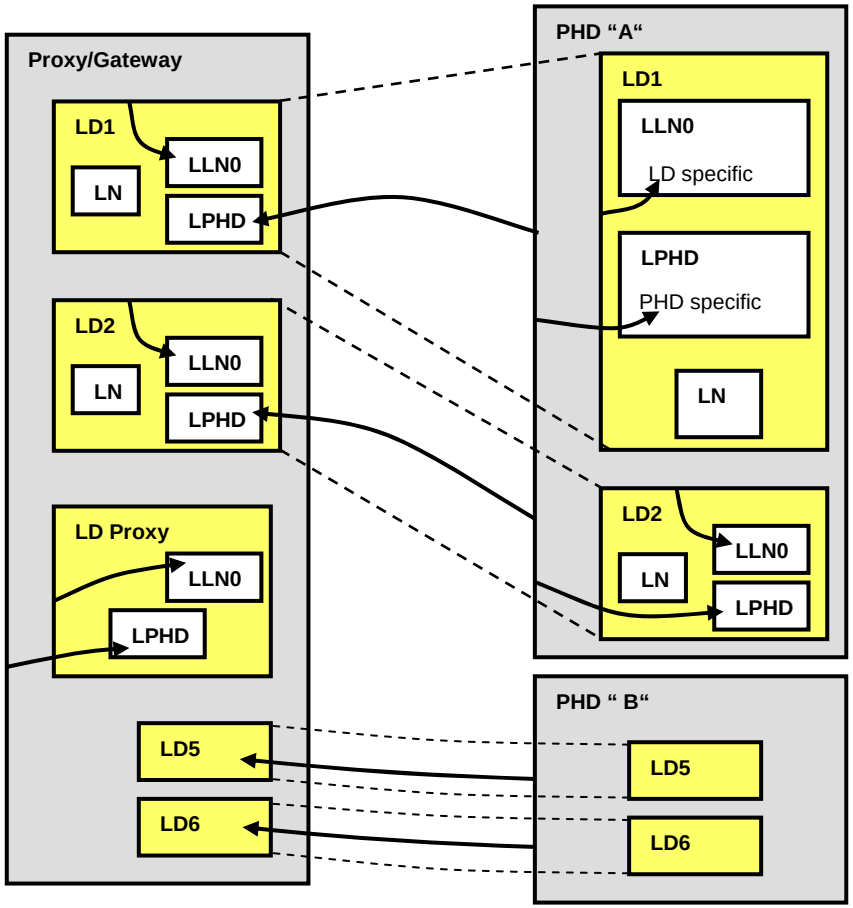
Basic Reference Model - Services



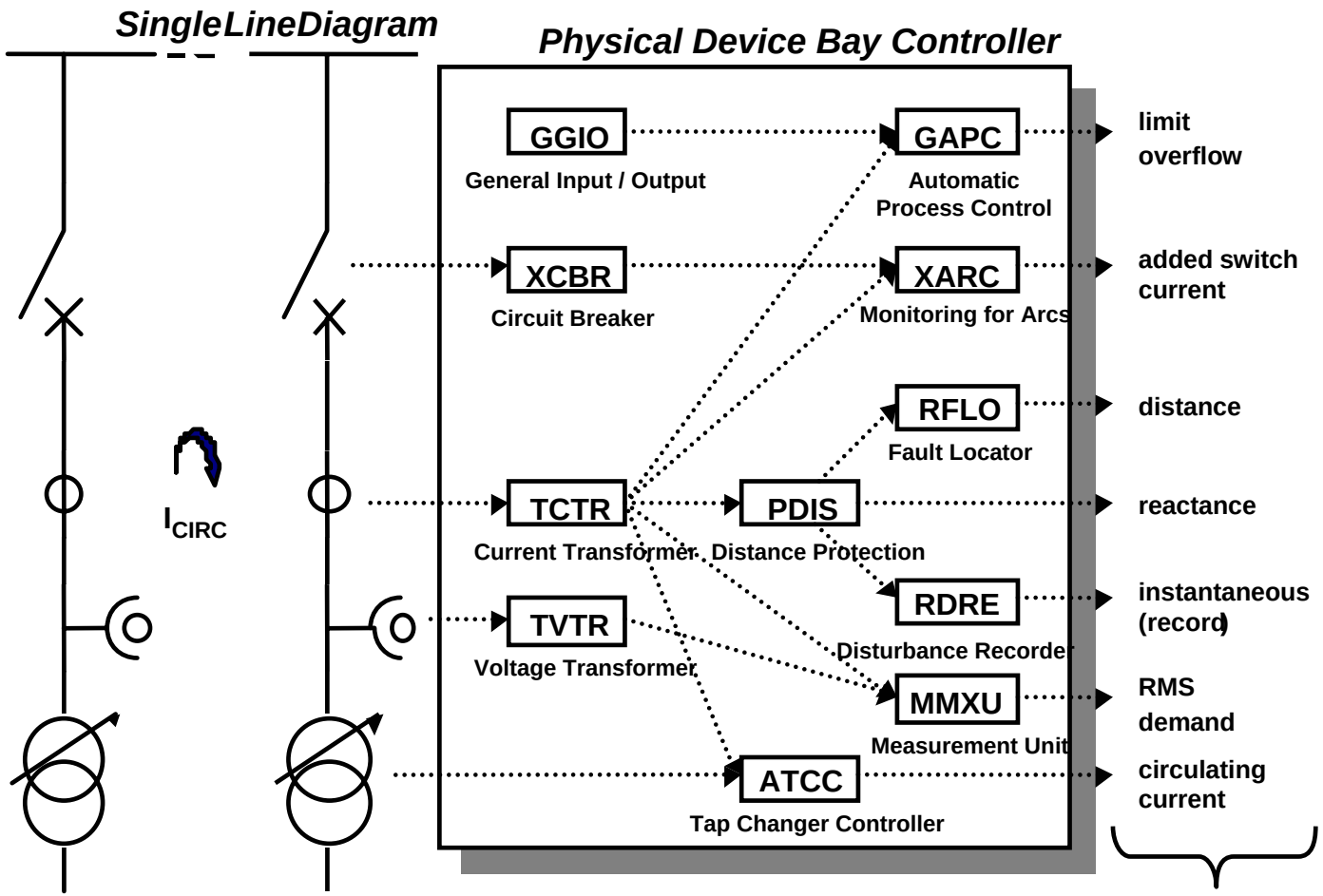
Server Building Blocks



Logical Devices as Proxy Servers



Mapping Example



Example for some current related information

IEC 61850 Standard - System Aspects

- **Part 1 - Introduction and Overview**
  - **An introduction and overview of the IEC 61850 standard series. It refers to and includes text and Figures from other parts of the IEC 61850 standard series.**
- **Part 2 - Glossary**
  - **A collection of specific terminology and definitions used in the context of Substation Automation Systems within the various parts of the standard.**

IEC 61850 Standard - System Aspects

- **Part 3 - General Requirements**
  - **Quality Requirements (reliability, maintainability, system availability, security)**
  - **Environmental conditions**
  - **Auxiliary Services**
  - **Other standards and specifications**

- **Part 4 - System and Project Management**
  - **Engineering (parameter classification, engineering tools, documentation)**
  - **System lifecycle (product versions, discontinuation, support after discontinuation)**
  - **Quality assurance (responsibilities, test equipment type tests, system tests, FAT and SAT)**

IEC 61850 Standard - System Aspects

- **Part 5 - Communication Requirements for Functions and Device Models**
  - **Logical interfaces**
  - **Requirements and interoperability**
  - **Substation automation system functions:**
    - **Function categories and list of functions**
    - **Specification of functions**
    - **Performance requirements of functions**
  - **Logical nodes and PICOMs**
    - **Concept**
    - **Logical node categories and list of logical nodes**
    - **The use of logical nodes, interaction of logical nodes**
    - **Specification of message types with performance requirements**
    - **List of PICOMs and classification of PICOMs to message types**
  - **Performance calculations for typical substation configurations**

IEC 61850 Standard - Configuration

- **Part 6 - Substations automation system configuration language**
  - **Overview of intended system engineering process**
  - **Definition of system parameter exchange file format based on XML containing:**
    - **primary system schematic (single line) description**
    - **Communication connection description**
    - **IED capabilities**
  - **Allocation of logical instances to primary system**
  - **Allocation of logical nodes to physical devices.**

IEC 61850 Standard - Data Modelling

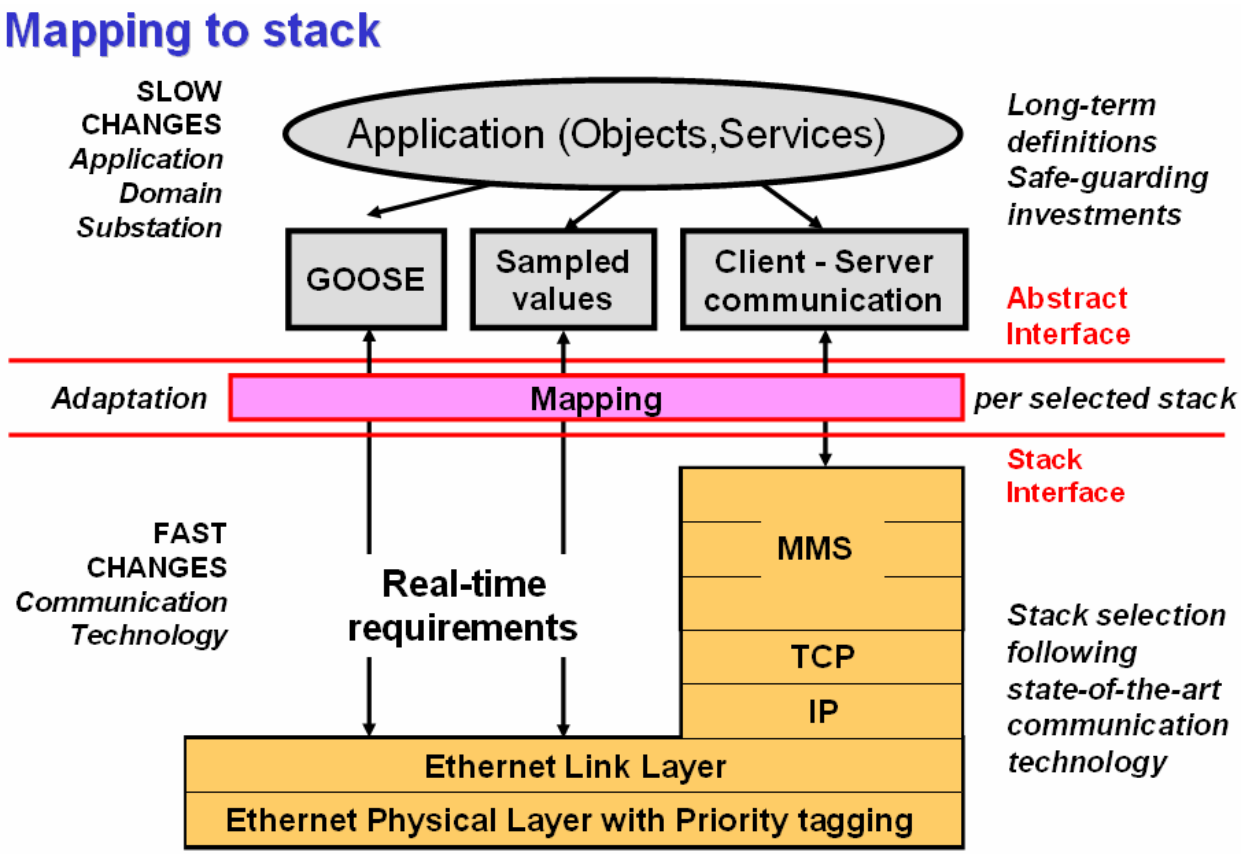
- **Part 7 Basic Communication Structure for Substation and Feeder Equipment**
- **Part 7-1 Principles and Models**
  - **Introduction to part 7-x**
  - **Concepts of communication modeling in IEC 61850**
- **Part 7-2 Abstract Communication Service Interface**
  - **Specification of abstract communication models and services**
  - **Concepts of hierarchical object model**

IEC 61850 Standard - Data Modelling

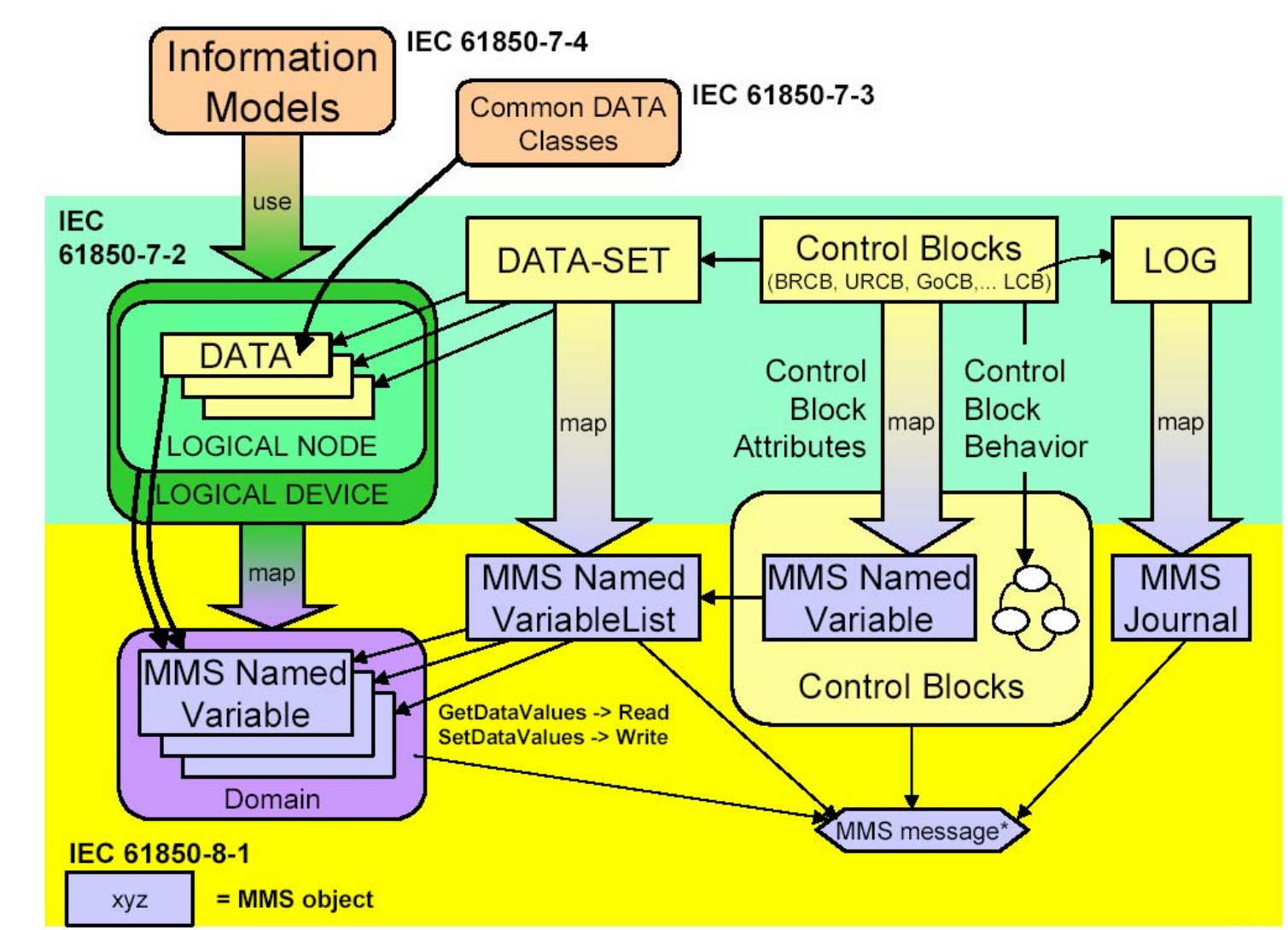
- **Part 7-3 Common Data Classes**
- **Part 7-4 Compatible Logical node classes and data classes**
  - **Definitions of logical node classes and data classes**
  - **logical node classes are composed of data classes**

IEC 61850 Standard - Station Bus Mapping

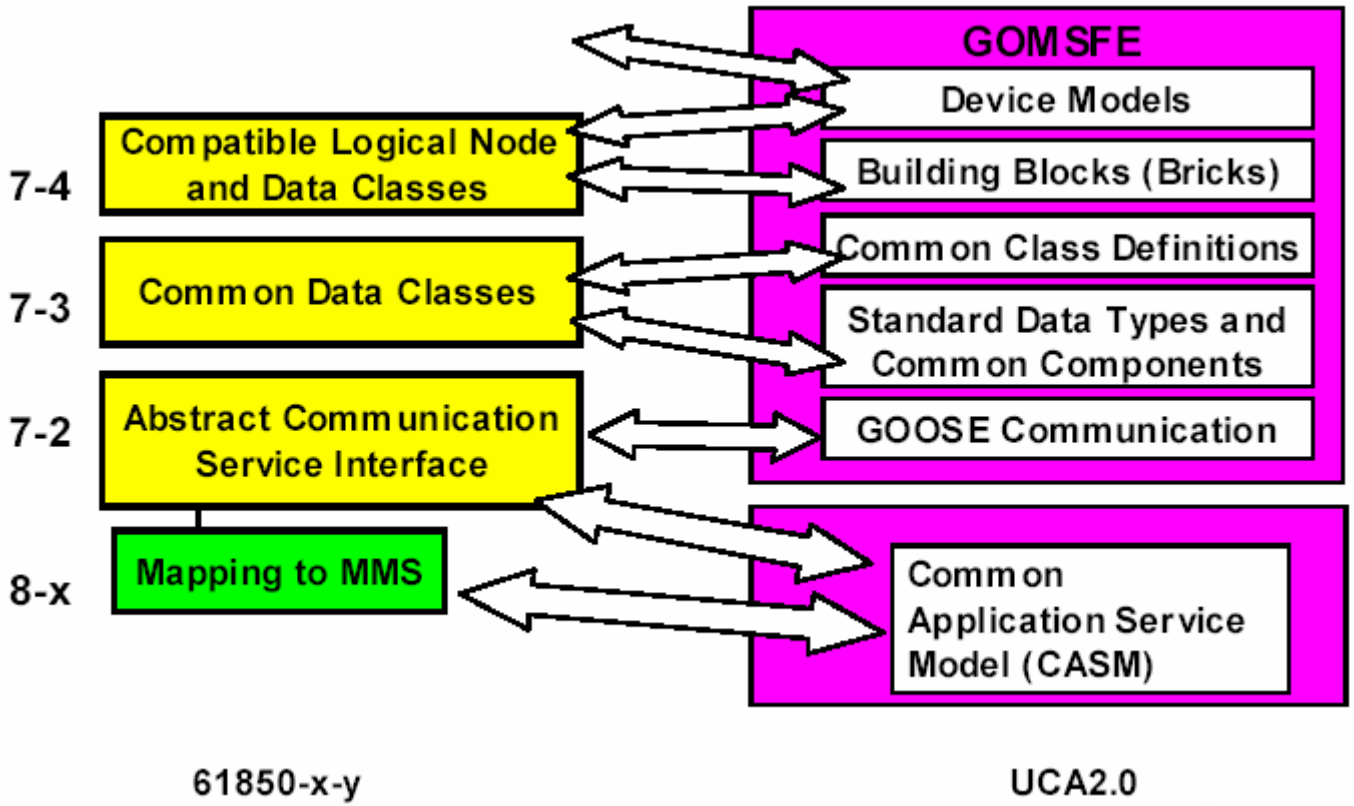
- **Part 8-1 - Mapping to MMS and ISO/IEC 8802-3**
  - **Mapping of communication models from part 7-2 except the model for transmission of sampled values**



Mapping to MMS



IEC61850 & UCA2 Correlation



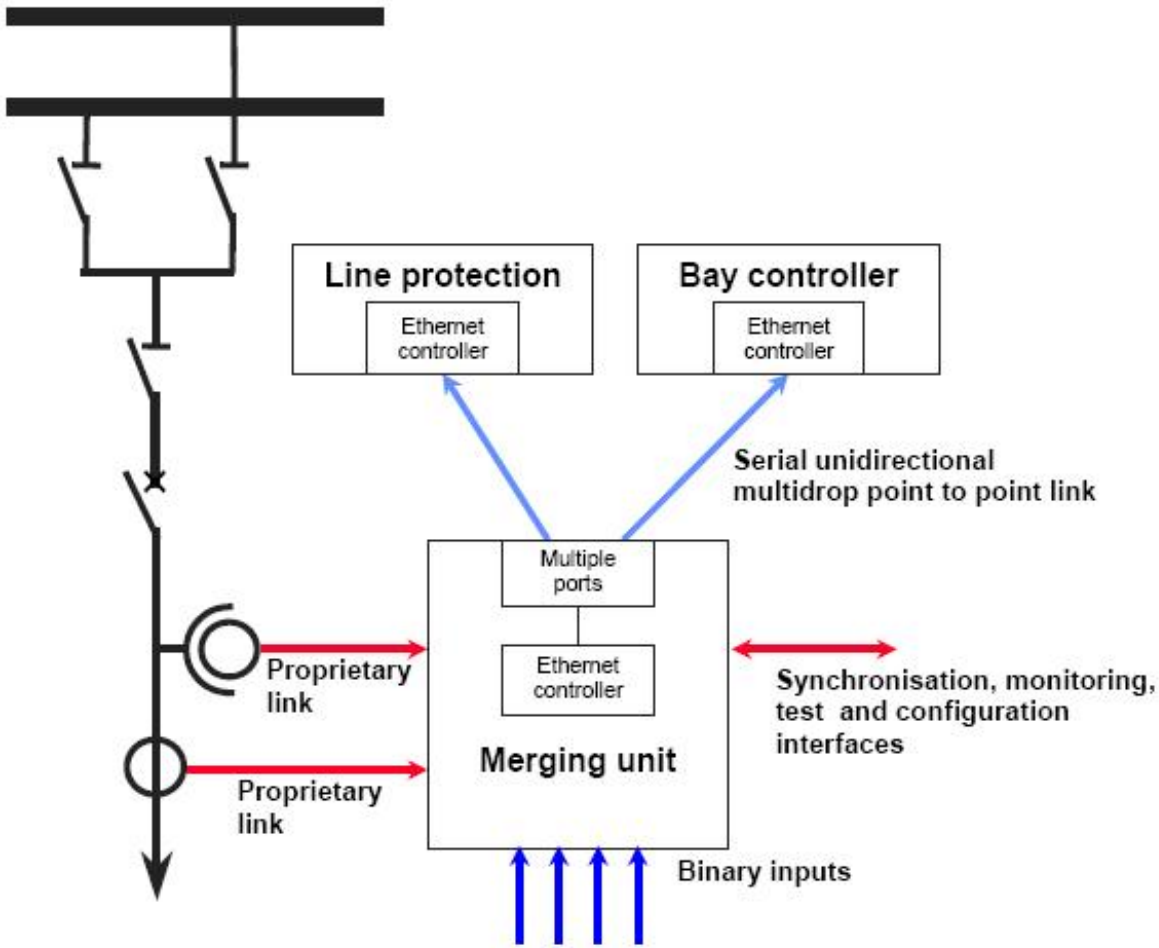
IEC 61850 Standard - Process Bus Mapping

- **Part 9-1 - Sampled values over serial unidirectional multi-drop point to point link**
  - **Mapping of the core elements from the model for transmission of sampled measured values**
  - **Use of IEEE 802.3**

- **Part 9-2 Sampled values over ISO/IEC 8802-3**
  - **Mapping of the complete model for transmission of sampled measured values and the model for generic object orineted system events (GOOSE)**
  - **The mapping of the other models of part 7-2 is according to part 8-1**

IEC 61850 Standard - Scope

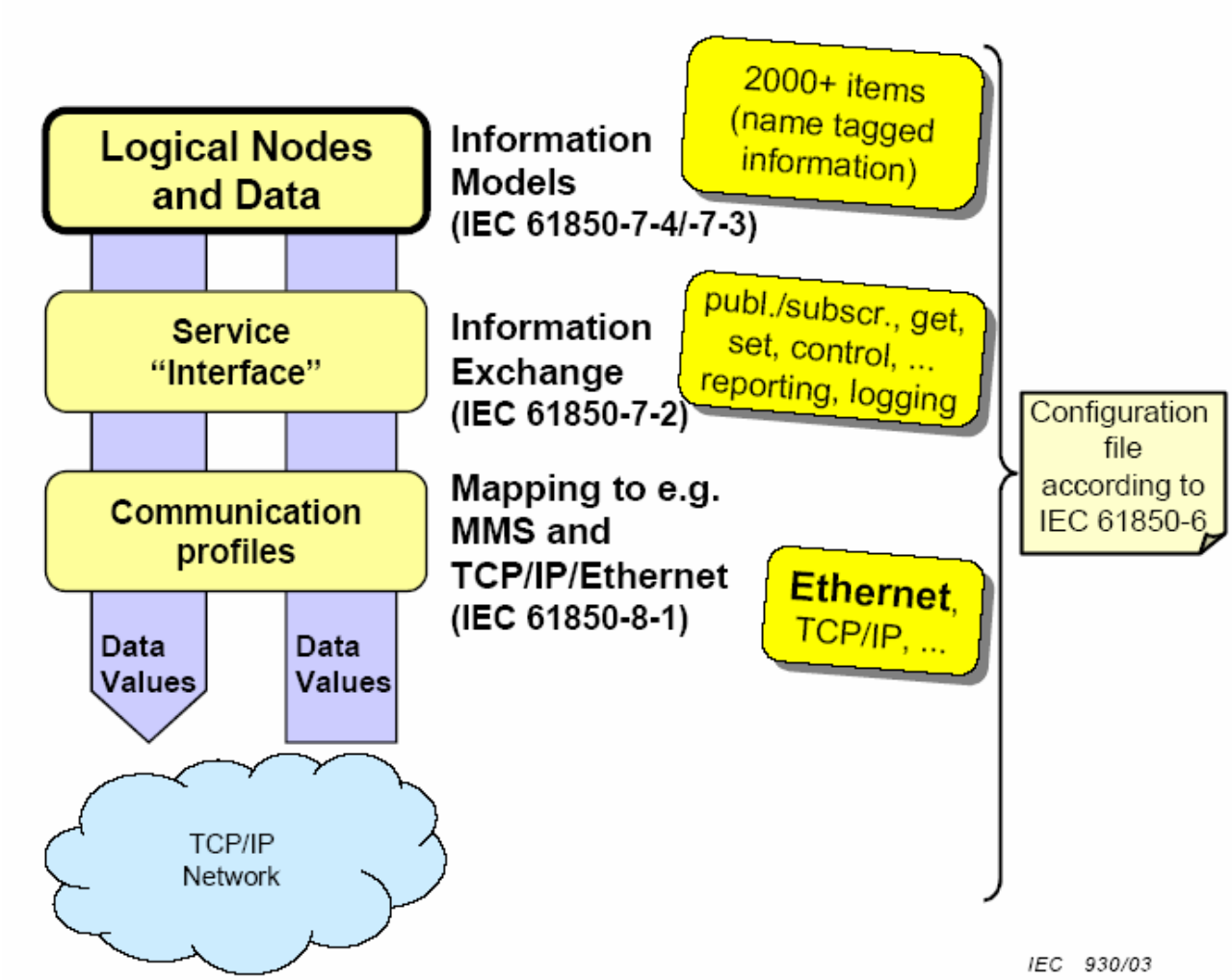
- **Part 9-1 (contd.)**



IEC 61850 Standard - Conformance

- **Part 10 - Conformance Testing**
  - **Conformance test procedure**
  - **Quality assurance and testing**
  - **Required documentation**
  - **Device related conformance testing**
  - **Certification of test facilities, requirement and validation of test equipment**

IEC 61850 Standard - Summary



IEC61850 Key Benefits (1)

- **Speed: 100 Mbps instead of few 10 kbps**
  - **More data for a better operation & maintenance**
- **Peer-to-peer: No extra hardware**
  - **Design of innovative automation schemes, late tuning**
- **Conditional report instead of polling**
  - **Optimal performances**
- **IP (Internet Protocol) routing: Ubiquitous data access**
  - **Capability to extend the system outside of the substation**

A true step forward

IEC61850 Key Benefits (2)

- Client-server: Instead of master-slave
  - Flexible designs easy to upgrade
- Pre-defined names: Single vocabulary between users
  - Easier engineering between teams
- XML references: Formal interfaces
  - Consistency between engineering tools
- IEC 61850 is independent of short term benefits: focuses on the “long living application objects”

IEC61850 Key Benefits (3)

- Independent of current product; stable over several product cycles (long term stability)
- Independent of operating systems and programming languages
- independent of middleware
- Independent of communication systems
- Independent of vendor (multi-vendor support)