RTDS Technologies

twenty years as the world standard for

REAL TIME DIGITAL SIMULATION

RTDS® South African Users' Group Meeting 2016

Agenda

GOOSE Message?

Sampled Values?

Ethernet ?

Changes in Edition 2

Questions and Answers

Part I

GOOSE MESSAGE

GOOSE MESSAGE

- Generic Object Oriented Substation Event (GOOSE)
- Fast and reliable distribution of information
  - Status (breaker position, trip, pickup, alarms, etc.)
  - Analog (counter values, etc.)
- Performance Requirements
  - Type 1A “Trip”: The trip is the most important fast message and most demanding requirements

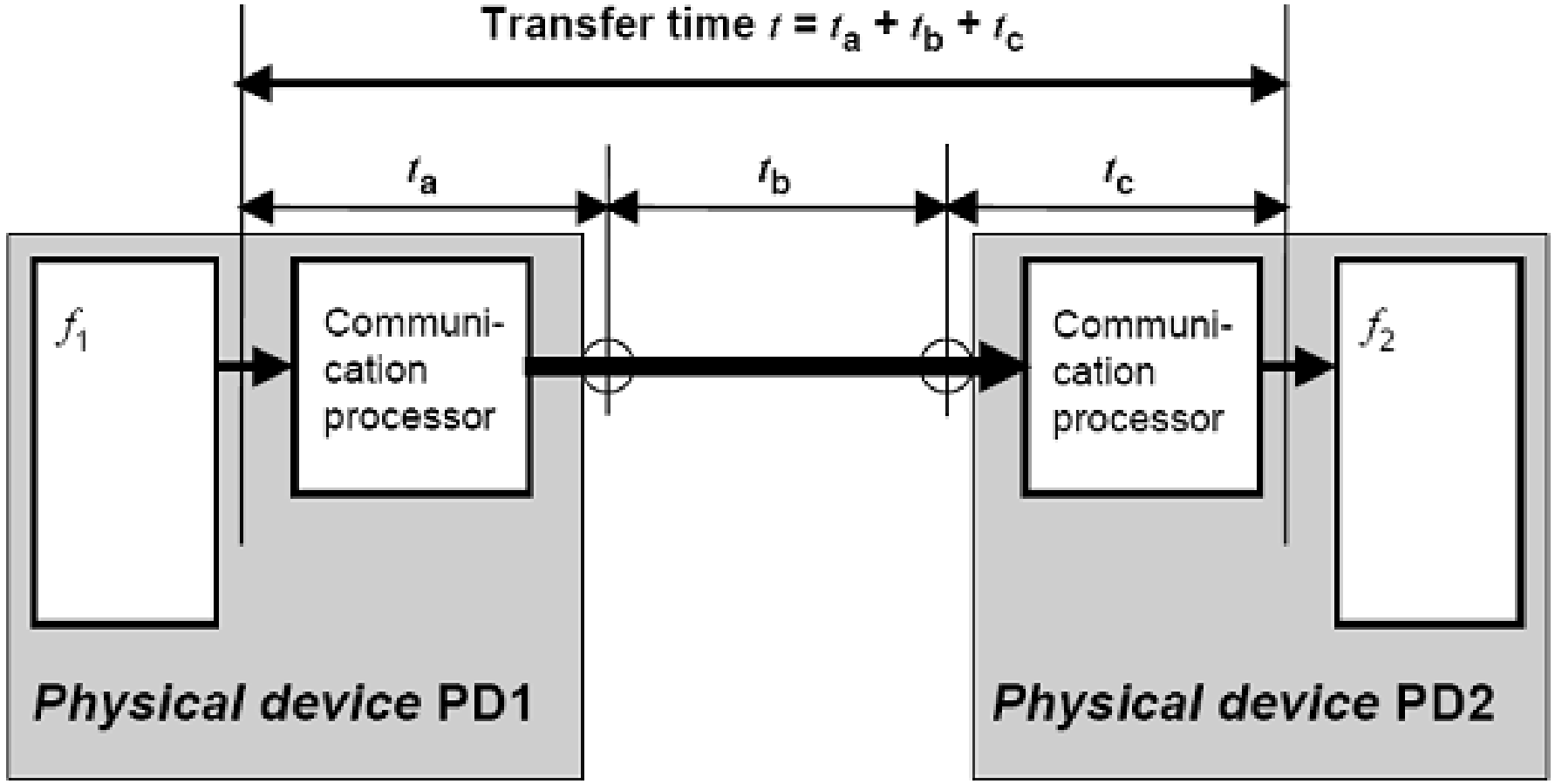
GOOSE MESSAGE

- Type 1A “Trip”: Performance Requirements
  - For Performance Class P1, the total transmission time shall be in the order of half a cycle. Therefore, 10 ms is defined
  - For Performance Class P2/3, the total transmission time shall be below the order of a quarter of a cycle. Therefore, **3 ms** is defined

Note: The same performance may be requested for interlocking, intertrips and logic discrimination between protection functions Performance

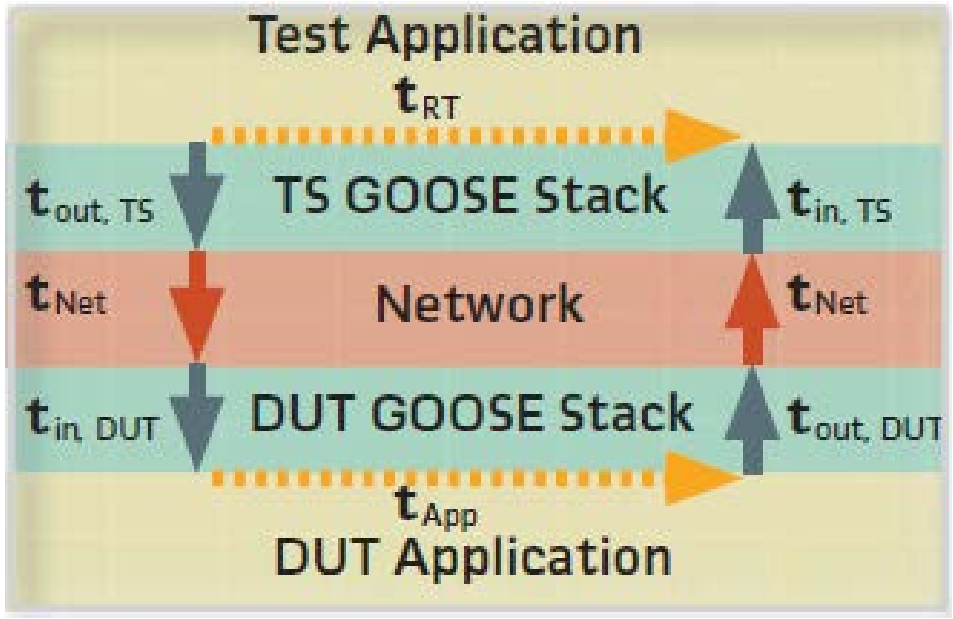
GOOSE MESSAGE

- IEC 61850-5 defines the transmission time as follows



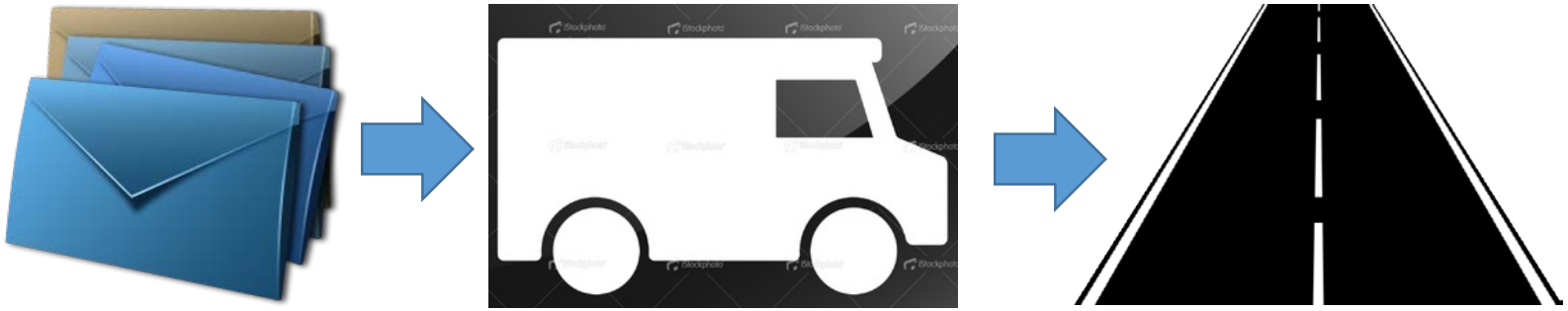
GOOSE MESSAGE

- The normal method for testing one GOOSE message is to do a test that sends and receives a GOOSE message from the device under test (DUT)
- The measured round-trip time is an aggregation of several delays in different layers



GOOSE MESSAGE

- ❑ GOOSE messages are based on change event
- ❑ GOOSE messages include diagnostic functions (a “heart beat” to all devices subscribed is sent periodically)
- ❑ GOOSE messages are managed by GCBs (GOOSE control block) inside IEDs
- ❑ GOOSE messages send “Data Sets” upon changes of state

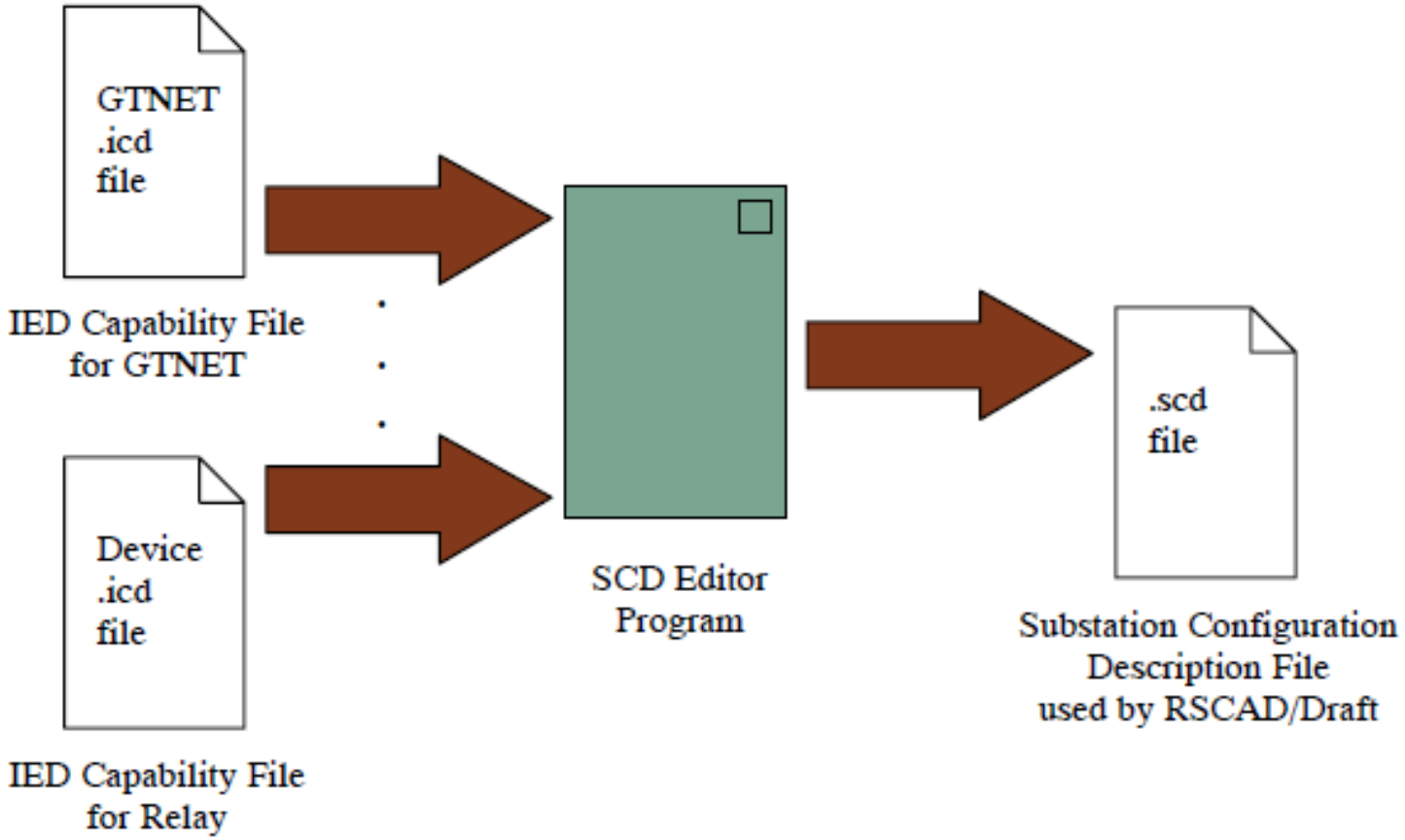


Data Set (Information) Goose Control Block (GCB) Network

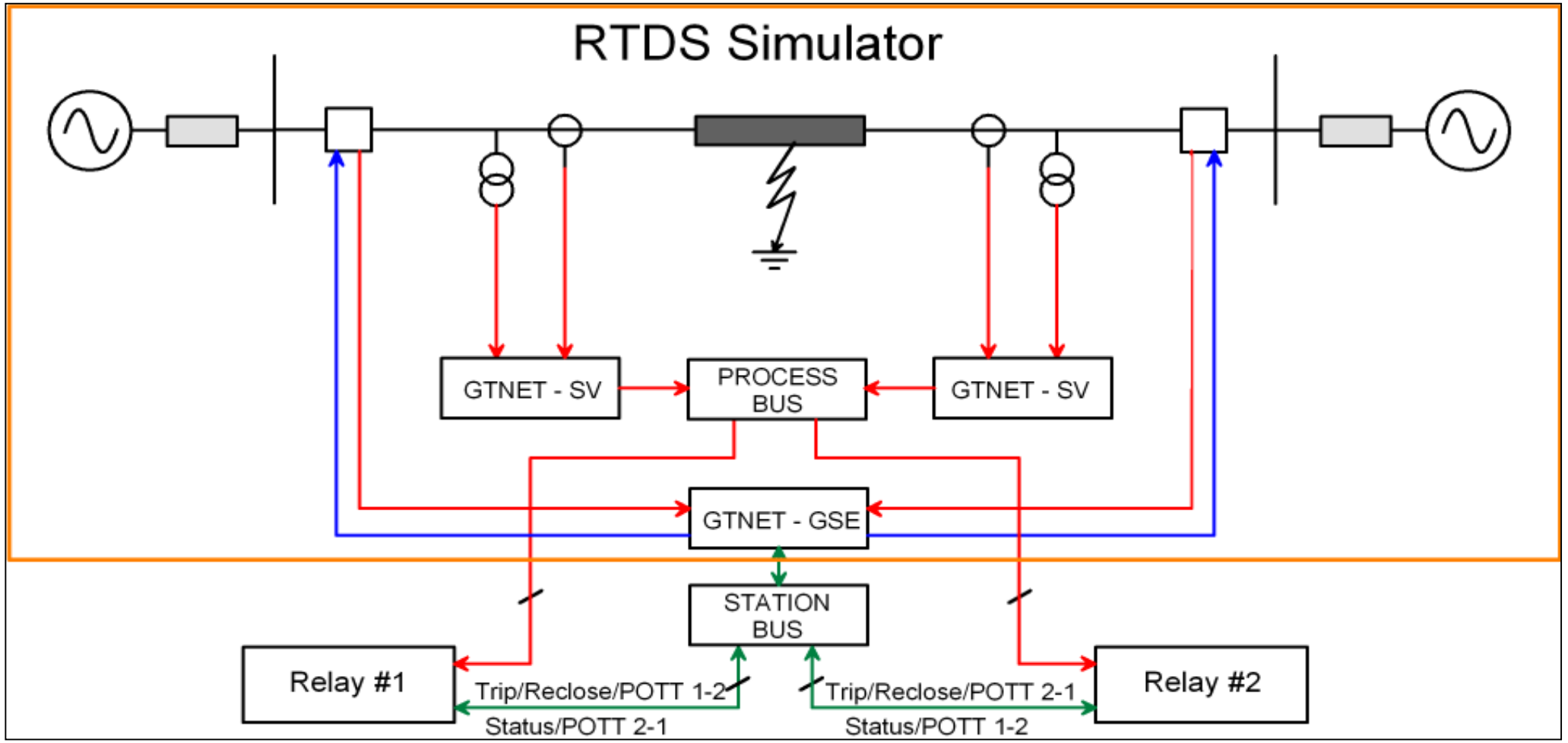
GOOSE MESSAGE

Configure a GOOSE message

- Starts with SCL files
  - SCD Substation Configuration Description
  - ICD IED Capabilities Description
  - CID Configured IED Description



GOOSE MESSAGE



Part II

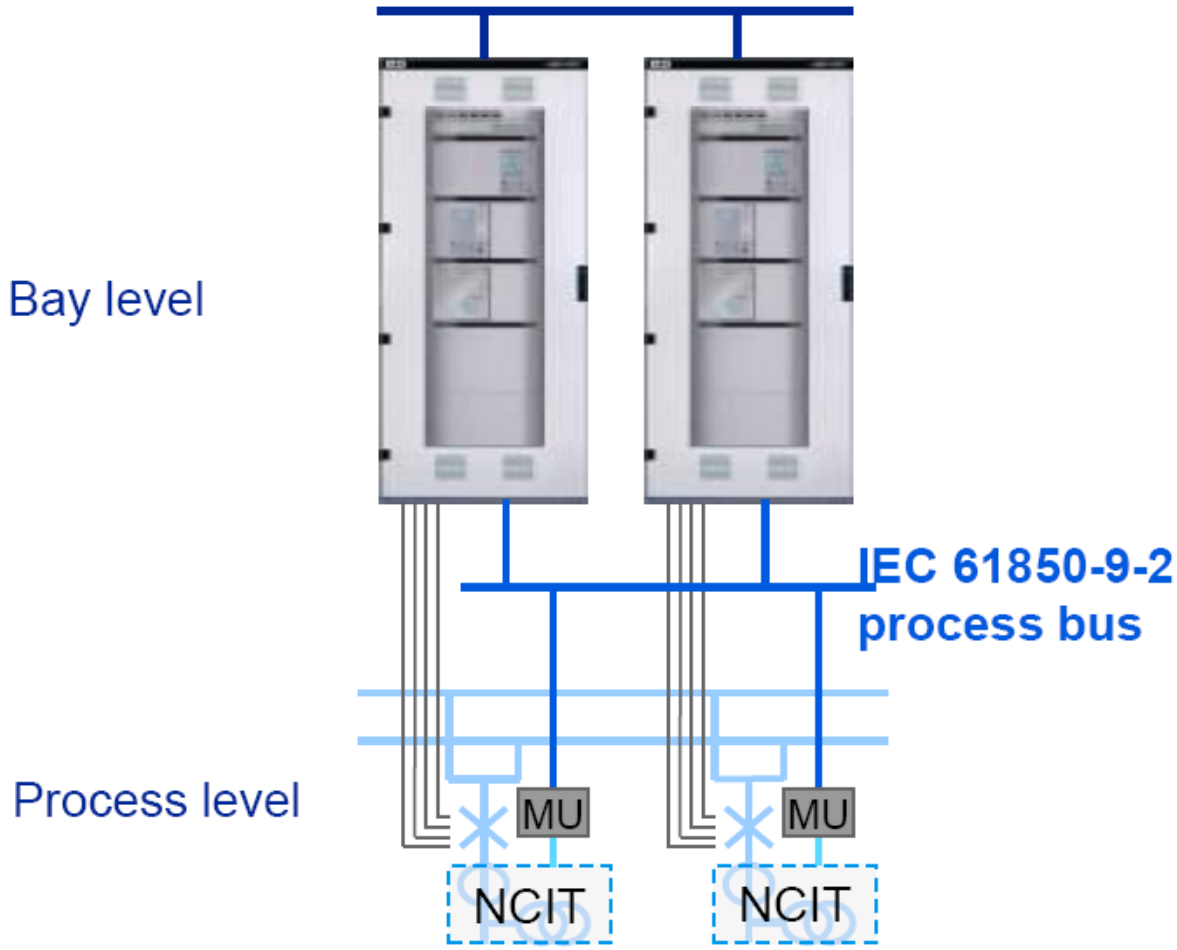
Sampled Values

SAMPLED VALUES

Introduction to process bus

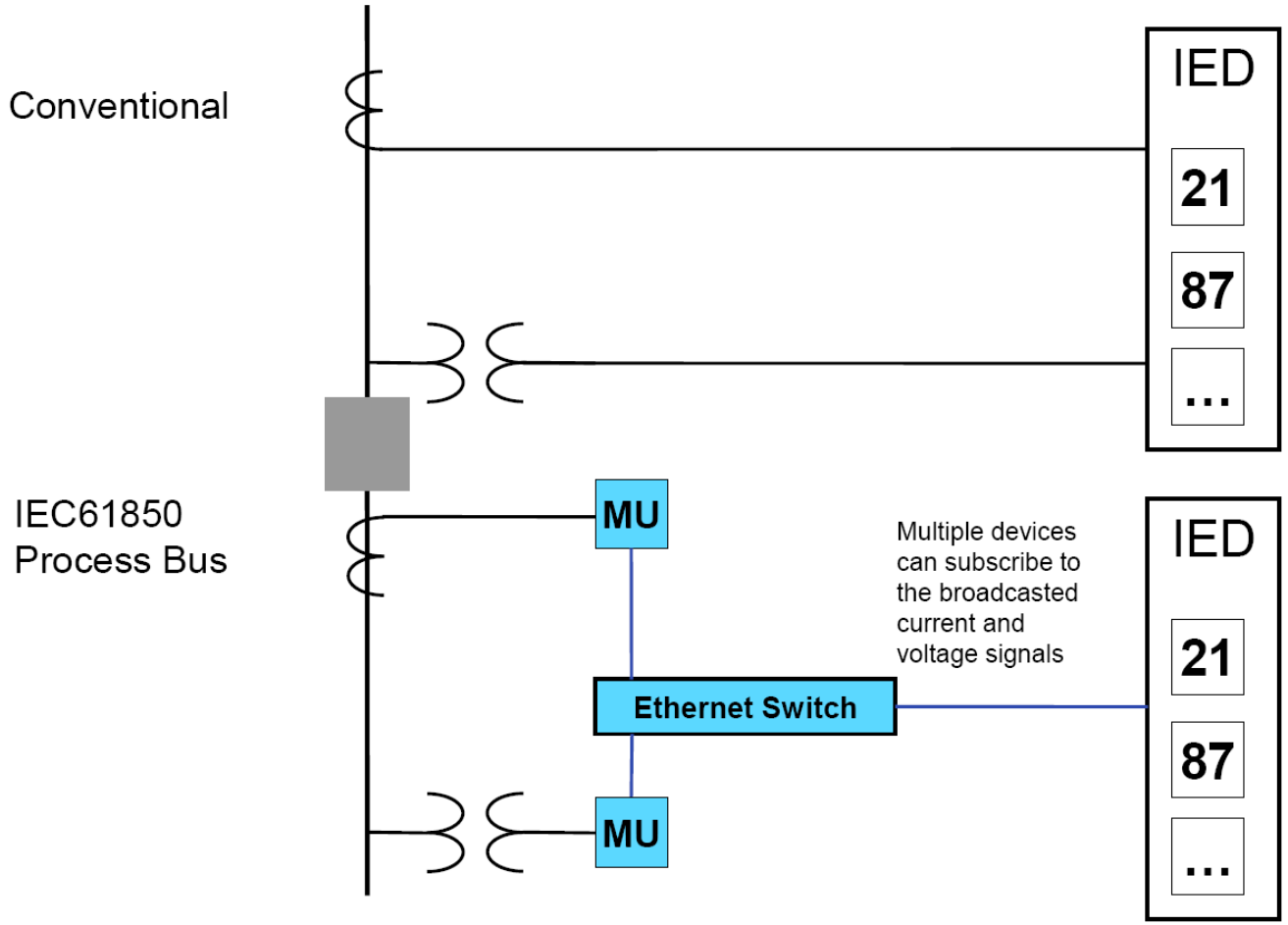
What is process bus

- The process bus is a communication network on process level, and also connecting the process to the bay level
- It is responsible for publishing the quantities related to the process, i.e.
  - Voltage
  - Current
- IEC 61850-9-2 describes the transmission of sampled analogue values over Ethernet
- “Sampled Values” are current and voltage samples obtained from CTs and VT/CVTs
- IEC 61850-9-2 defines the communication protocol over Ethernet that enables the publication of such samples for the purposes of protection, monitoring and metering



SAMPLED VALUES

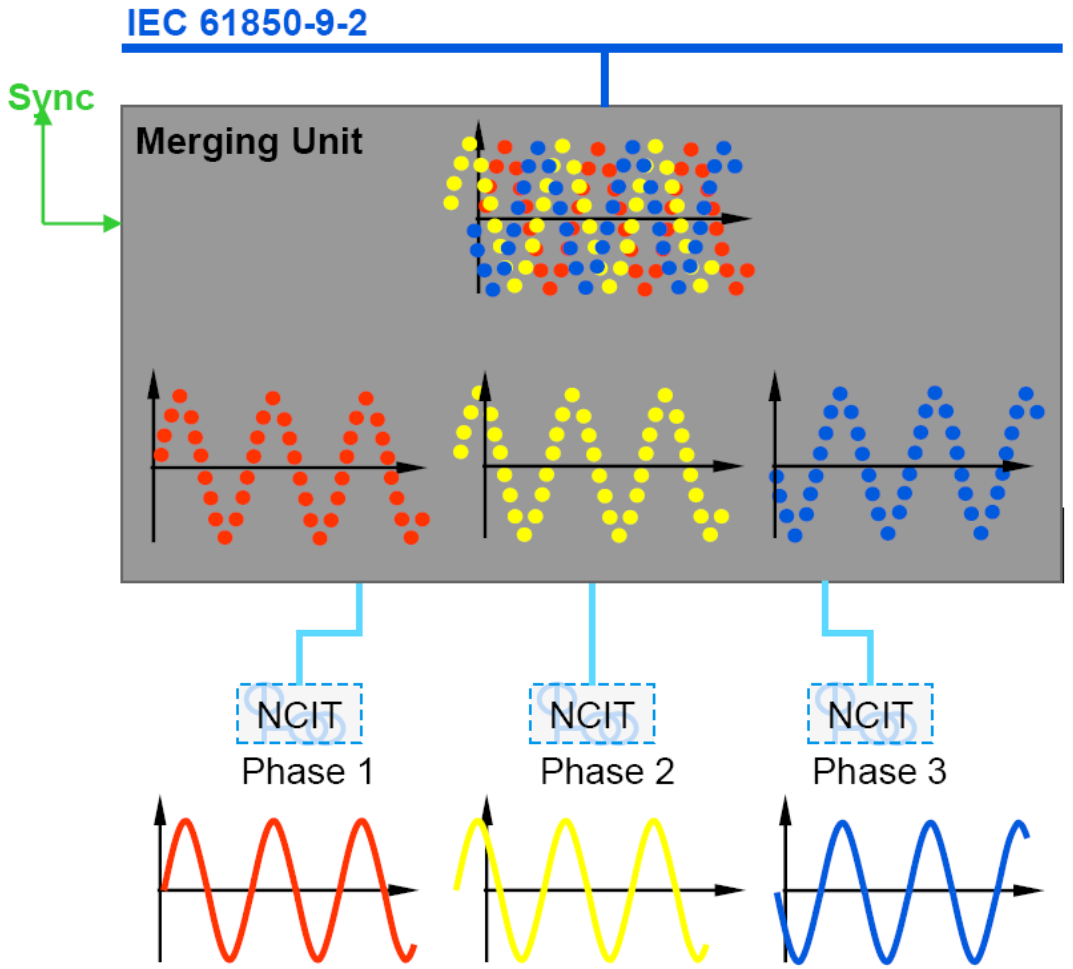
Introduction to process bus



SAMPLED VALUES

Merging Unit (MU)

- Communication interface based on IEC 61850-9-2
- Samples current/voltage signals from Non-Conventional Instrument Transformer (NCIT), merges them after time synchronization, then publishes the messages to the Ethernet
- Time synchronization is needed between the publisher (MU) and the subscriber (IEDs)



SAMPLED VALUES

IEC 61850-9-2 standard and implementation guideline

- **The standard: IEC 61850-9-2**
  - Communication networks and systems in substations Part 9-2: Specific Communication Service Mapping (SCSM) - Sampled values over ISO/IEC 8802-3
    - The standard leaves wide room for implementation and considerable effort is required for full implementation
- **Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2**
  - To facilitate implementation, the UCA International Users Group created an implementation guideline that defines a subset of IEC 61850-9-2.
    - Commonly referred to as IEC 61850-9-2LE for “light edition”

SAMPLED VALUES

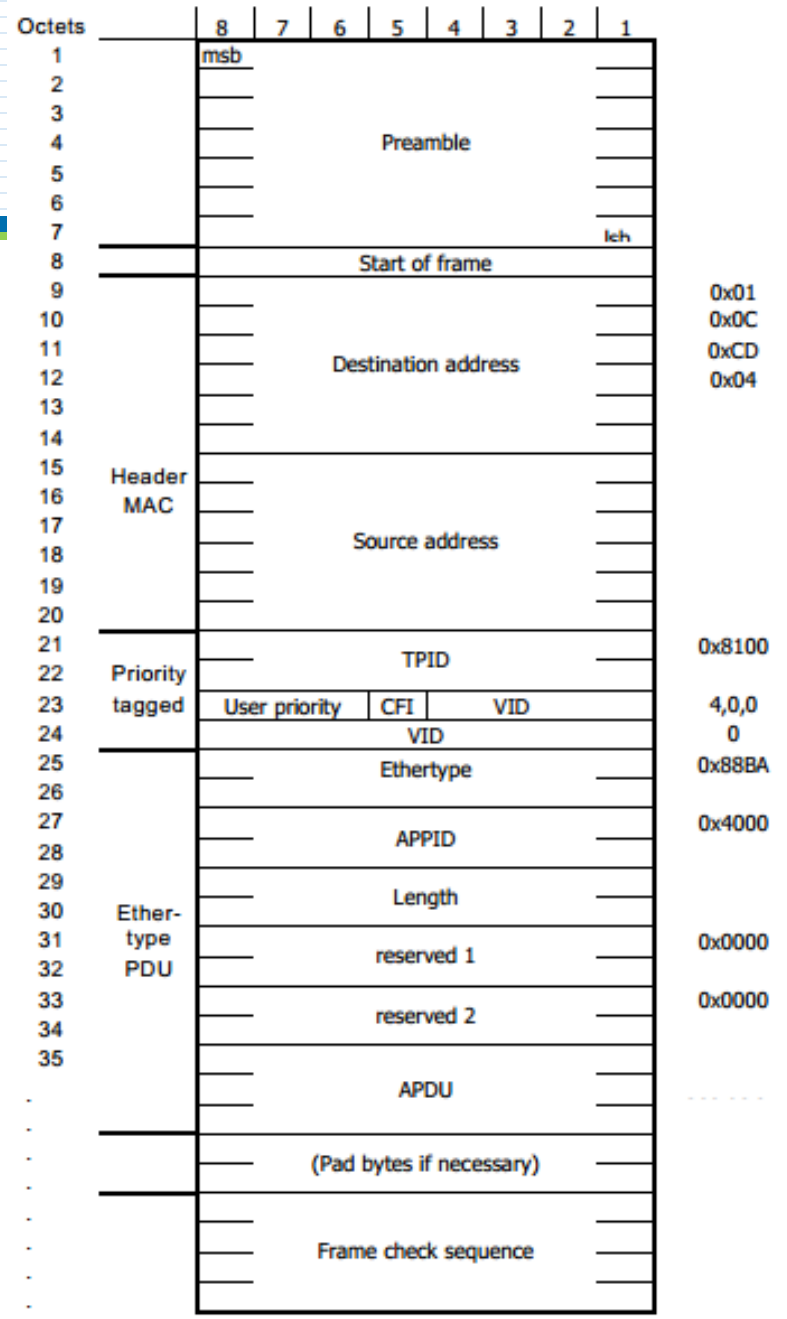
Comparison - IEC standard vs. UCA Users Group Implementation Guideline

Category	Standard IEC 61850	Implementation Guideline (IEC 61850-9-2LE)
Sampling rate	Not defined	80 samples per cycle for protection and metering; 256 samples per cycle for power quality
Dataset	Configurable	3 phases current + neutral 3 phases voltage + neutral
Time synchronization	Not defined	Optical pulse per second (1PPS)
Logical device “Merging Unit”	Content and naming are not specified	Logical device (LD) name, logical nodes (LN) are specified

SAMPLED VALUES

61850-9-2 Ethernet Frame

- Destination: multicast mac address
- Source: source mac address
- Vlan info (Priority tagged)
- Ethertype: 0x88BA
- Ethertype APPID: 0x4000
- Sampled Values Protocol Data Unit (APDU)



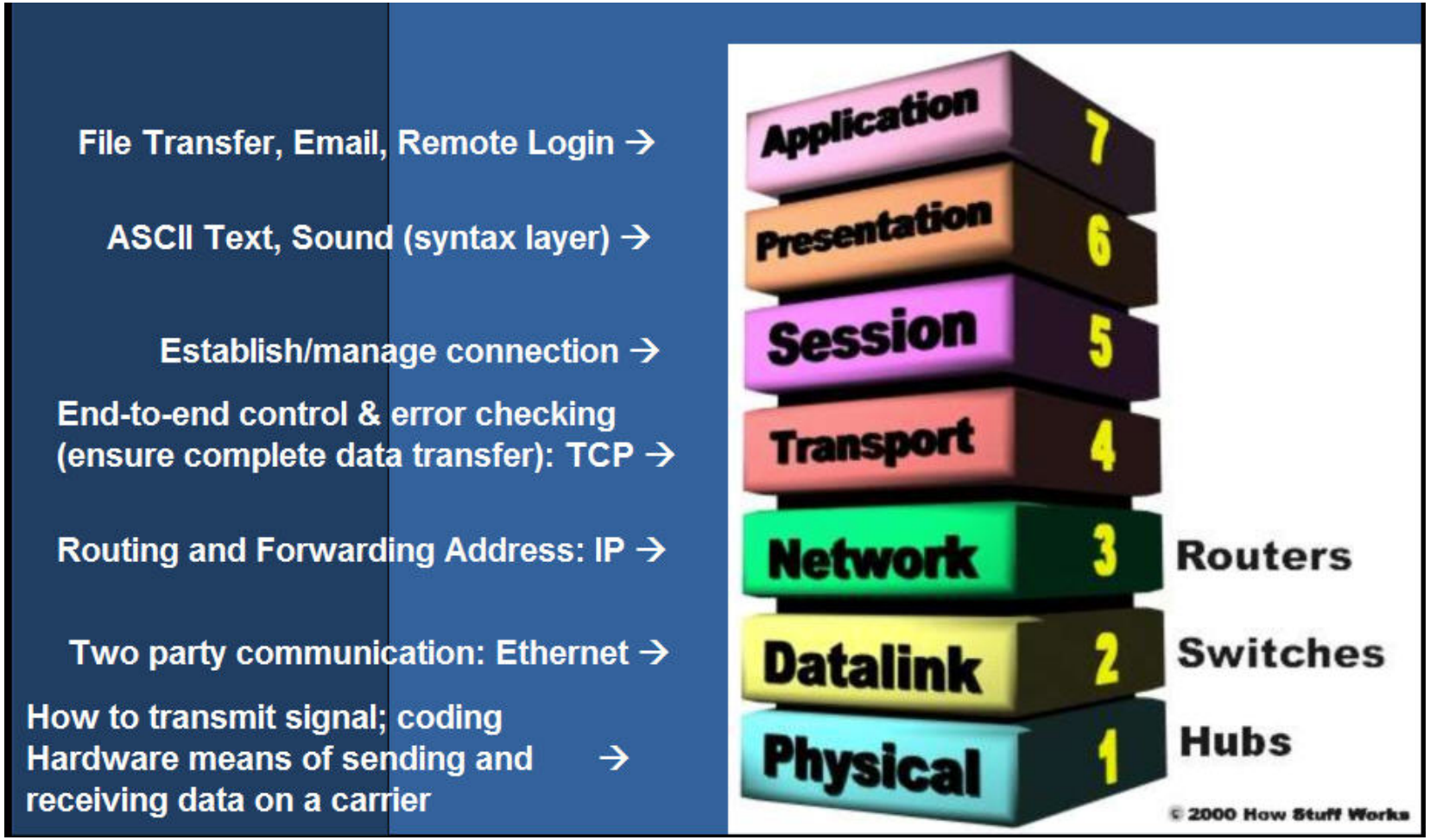
Part III

Ethernet

ETHERNET

What is Ethernet?

- Originally developed by the Xerox Corporation in the 1970s
- Layered protocol
- Includes definitions regarding media



ETHERNET

ISO/OSI Model

7	Application Layer	TimeSync SNTP	SV Sampled Values	GOOSE Generic Object Oriented Substation Event	GSSE Generic Substation Status Event MMS ISO 9506 Connectionless ACSE ISO/IEC 8649,10035	MMS ISO 9506 Core ACSI Services Connection-oriented ACSE ISO/IEC 8649,8650	
6	Presentation Layer	n/a	n/a	ASN.1, BER ISO/IEC 8824.1	Connectionless presentation ISO/IEC 8649,10035 ASN.1, BER ISO/IEC 8824.1	Connection-oriented presentation protocol ISO/IEC 8822,8823 ASN.1, BER ISO/IEC 8824.1	
5	Session Layer	n/a	n/a	n/a	Connectionless session ISO/IEC 9548	Connection-oriented session ISO/IEC 8326,8327	
4	Transport Layer	UDP/IP	n/a	n/a	GSSE T-Profile ISO/IEC 8602	ISO CO T-Profile ISO/IEC 8073	TCP/IP T-Profile ISO Transport on top of TCP (RFC 1006)
3	Network Layer	IP (RFC 791)	n/a	n/a	ISO/IEC 9542	ISO/IEC 8473	IP (RFC 791)
2	Link Layer	RFC 894	Priority Tagging/VLAN (IEEE 802.1Q) CSMA/CD (ISO/IEC 8802.3)		ISO/IEC 8802-2 LLC		RFC 894
1	Physical Layer	ISO/IEC 8802.3 Ethertype			ISO/IEC 8802.3		ISO/IEC 8802.3 Ethertype

ETHERNET

Ethernet Frame

Preamble	Destination MAC address	Source MAC address	Type	PayLoad	CRC/FCS

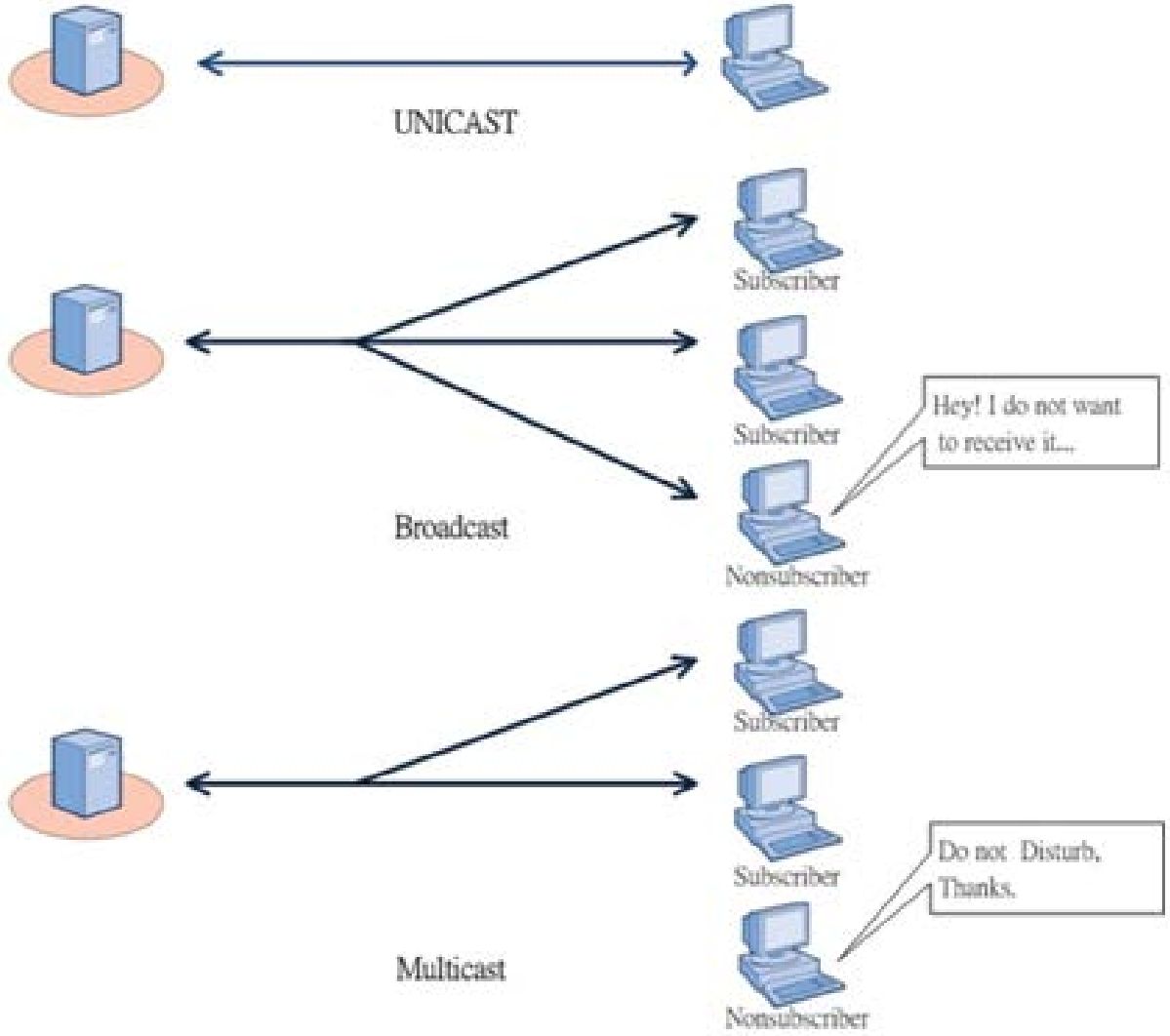
Preamble	Destination MAC address	Source MAC address	**802.1Q header** (VLAN ID)	Type	PayLoad	Recalculated field CRC/FCS

Insertion of 802.1Q Tag (VLAN ID) in Ethernet-II frame

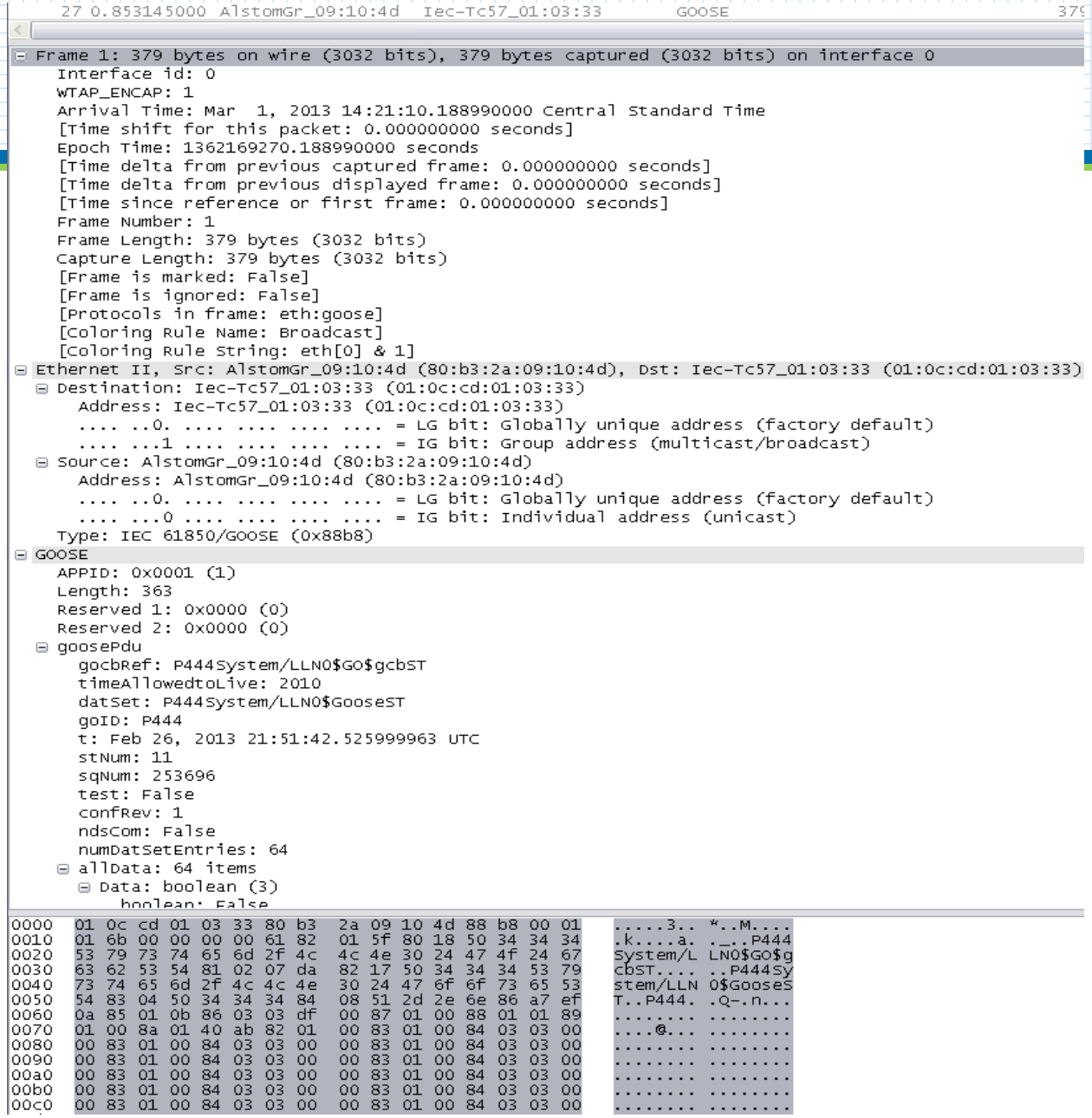
ETHERNET

What is Ethernet?

- Unicast
  - One station
  - 1 destination address (start with 00)
- Broadcast: network
  - All stations in the network
  - 1 destination address – ff:ff:ff:ff:ff:ff
- Multicast
  - Group of stations
  - 1 destination address that multiple stations are subscribed to (starts with 01)



ETHERNET



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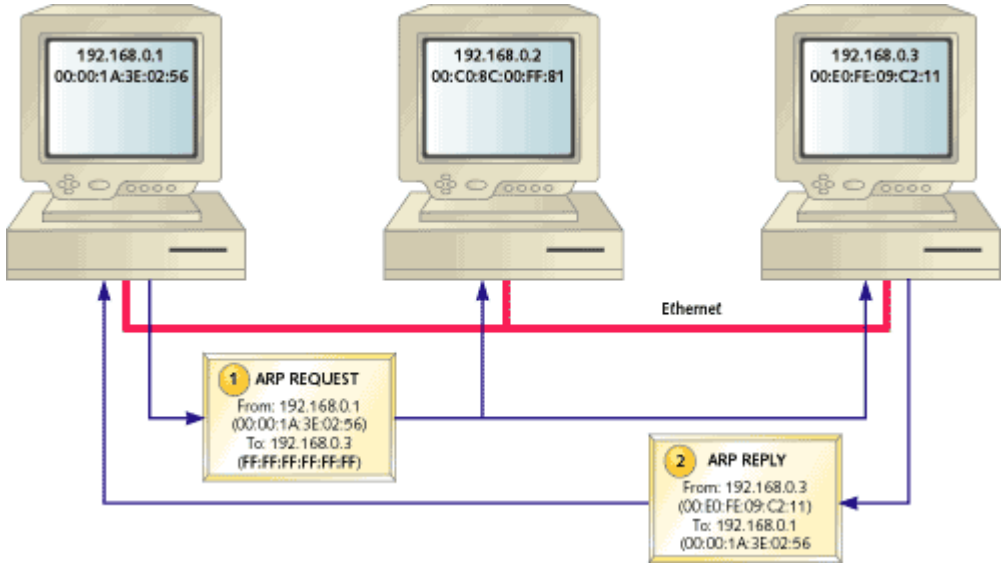
celebrating 20 years as the world standard for real time digital power system simulation

ETHERNET

- MAC (Media Access Control)
- Unique identifier that is 6 bytes long
- First 3 bytes correspond to OUI (Organization Unique Identifier) – For RTDS this value is 00:50:C2
- Remaining 3 bytes must be uniquely allocated by the organization to avoid duplicates
- When a station connects to a network its NIC card senses the electrical connection, resolves the media type (bit rate, encoding, etc.), and announces its presence

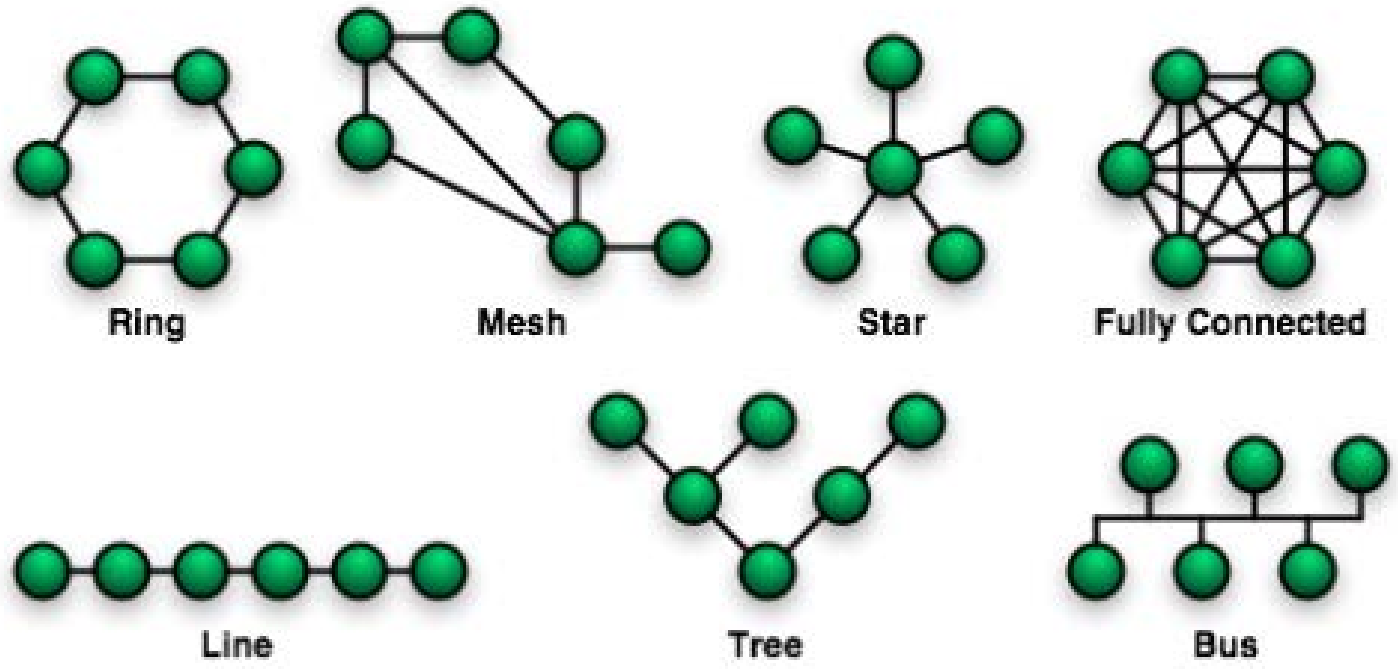
ETHERNET

- A station announces its presence in the network by sending an ARP message
- ARP = Address Resolution Protocol
- Broadcast message (ff:ff:ff:ff:ff:ff)
- All connected stations take note of this in their ARP table
- Switches use this information to match a destination MAC address with a port number (lookup table)



ETHERNET

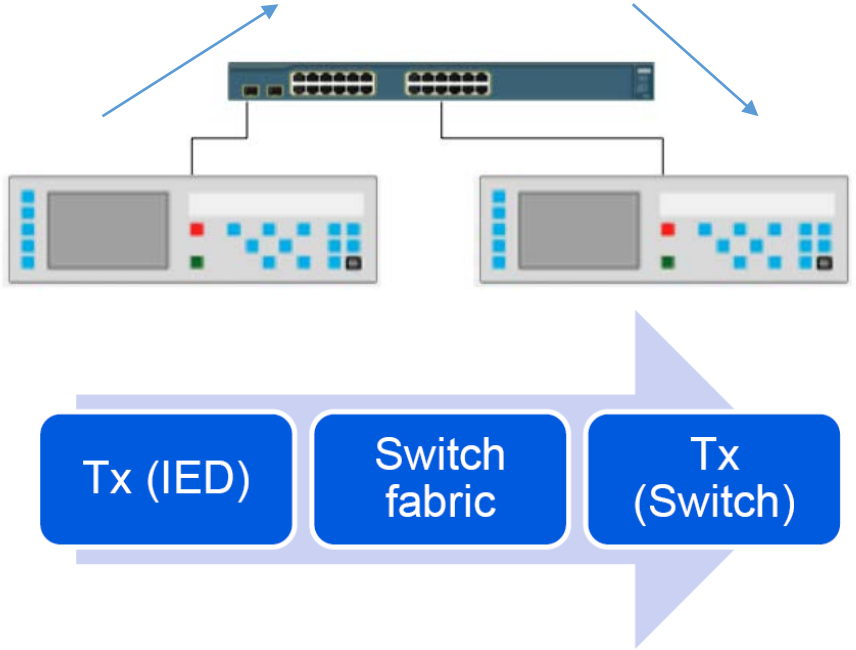
Topologies



ETHERNET

Ethernet Switching

- "Switch" frames from one port to another
  - Cut-through
  - Store and Forward
  - Fragment free
- Four steps:
  - Receive frame
  - Read destination MAC address
  - Determine destination port per lookup table
  - Transmit to the correct port



ETHERNET

The speed of Ethernet

By far, most installations utilize 100Mbps links for communications

$$tx\ or\ rx\ time = bits/bit\ rate + switch\ fabric + queuing + media$$

$$bit\ rate = 100Mbps \sim 1\ bit\ every\ 10\ nanoseconds$$

$$switch\ fabric = \sim 5\ microseconds$$

$$queuing = function\ of\ frame\ size, network\ speed, and\ network\ load \sim 3 - 5\ microseconds$$

$$media = <1\ microsecond\ for\ LAN$$

ETHERNET

The speed of Ethernet

A typical GOOSE message will be around 300 bytes (2400 bits)

$$tx\ or\ rx\ time = bits/bit\ rate + switch\ fabric + queuing + media$$

$$tx\ or\ rx\ time = 2400/100M + 0.000005 + 0.000005 + 0.000001 = 35\ microseconds$$

- Note that the typical travel time of an output contact is 4-6 milliseconds

In addition, a debounce time of 4-6 milliseconds is added

ETHERNET

Conclusion

- Ethernet becoming the predominant media inside substations
- Availability of equipment and standardization are the driving factors
- Although non deterministic by nature, modern Ethernet is highly reliable and suitable for Real Time Control Applications
- Bandwidth consumption should be taken into consideration when designing networks

Part IV

IEC 61850 Edition 2

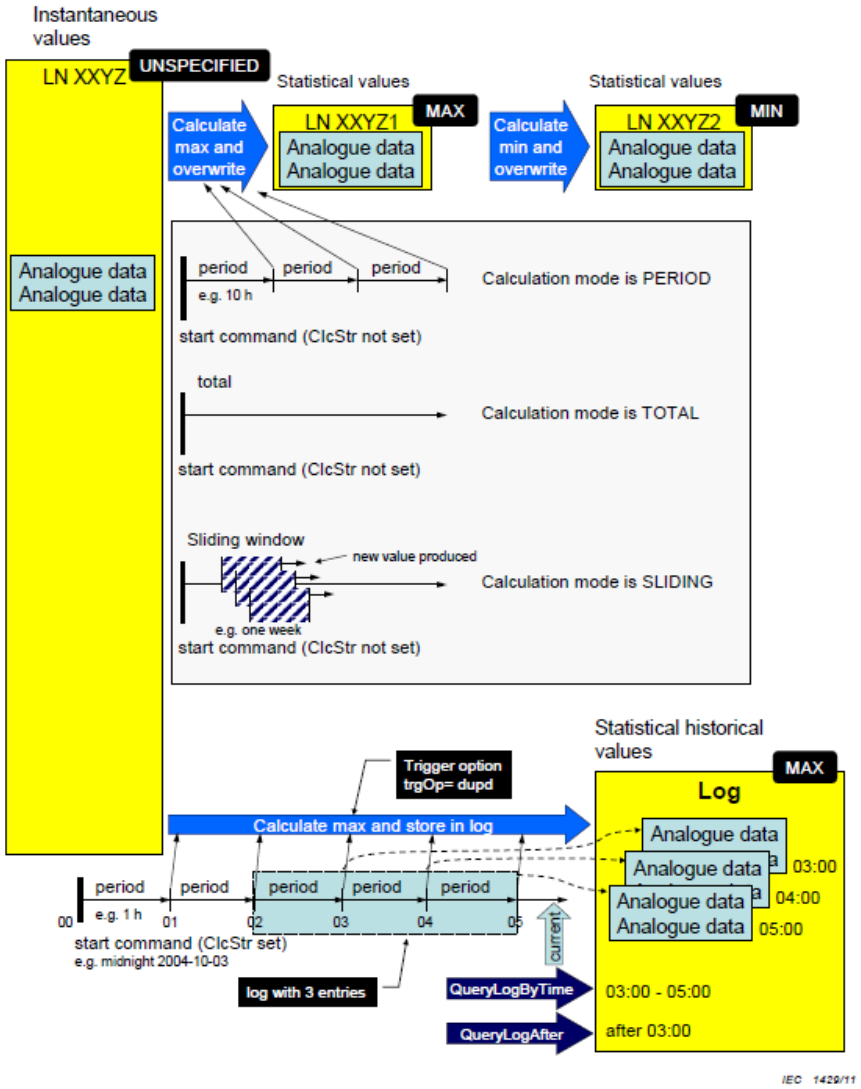
IEC 61850 Edition 2

- IEC 61850-7-1 series provides an overview of the architecture for communication and interactions between systems for power utility automation such as protection devices, breakers, transformers, substation hosts etc.
- Compared to the first edition, this second edition introduces:
  - the model for statistical and historical statistical data,
  - the concepts of proxies, gateways, LD hierarchy and LN inputs,
  - the model for time synchronization,
  - the model for GOOSE subscription and SV subscription monitoring
  - the extended logging function.
- It also clarifies the following points:
  - the use of numbers for data extension,
  - the use of name spaces,
  - the mode and behaviour of a logical node,
  - the use of range and deadbanded values,
  - the access to control actions and others.

Model for Statistical and Historical Statistical Data

- In many application domains, it is required to provide additional information of a basic analogue value:
  - statistical information (for example, minimum value calculated for a specified time period, for example, minimum value of last 1 h),
  - historical statistical information (for example, log of minimum values of the sequence of values calculated above, for example, last 24 hourly values).
- This additional information may be derived from the basic analogue values. It may be the only information provided – depending on the application requirements.

Model for Statistical and Historical Statistical Data



Proxies and Gateways

- Proxies are special devices that mirror logical devices located in other IEC 61850 physical devices. Hence, these logical devices are, from a functional point of view, transparent. They can be identified independently of their location (in a separate device connected to the network or in a proxy device).
- Gateways are network interconnection devices that translate protocols to other protocols. For example, gateways may convert non IEC 61850 data into IEC 61850 data.
- Logical devices allows for the building of proxies and/or gateways.
- Logical devices that mirror logical devices of other physical devices shall provide a LPHD that represents the remote physical device on which the original LD resides (e.g., A_LD1). These logical devices shall have the data LPHD.Proxy.stVal of the LPHD set to TRUE.

LN Inputs

- In Edition 1 there was use of Private Sections by all the manufacturers to help them use SCL files for configuration of the GOOSE subscription within the constraints of their IED configuration tool (ICT).
- Edition 2 introduced the concept of using a common method to describe the data flow between Logical nodes.
  - This new concept is still being worked out by IEC TC57/WG10 and will be part of Edition 2.1
  - Generic LN input references are used to describe incoming signals from an external source, i.e. reference to data coming from an LN hosted by the same IED or by another IED and its binding to an IED specific internal address. It is also possible to describe the intended purpose of the incoming signal. LN input references are defined by the instantiation of data named InRef and the use of the common data class ORG, “object reference setting group”.

Time Synchronization

- Time synchronization provides the accurate time for time tagging (ms range) in applications such as reporting and logging or for applications such as synchronised sampling (µs range).
- This service category is described in IEC 61850-7-2
- Time synchronization shall meet the requirements of IEC 61850-5; the specification of time synchronization is defined in the specific communication service mapping (SCSMs) (for example, SNTP for IEC 61850-8-1);

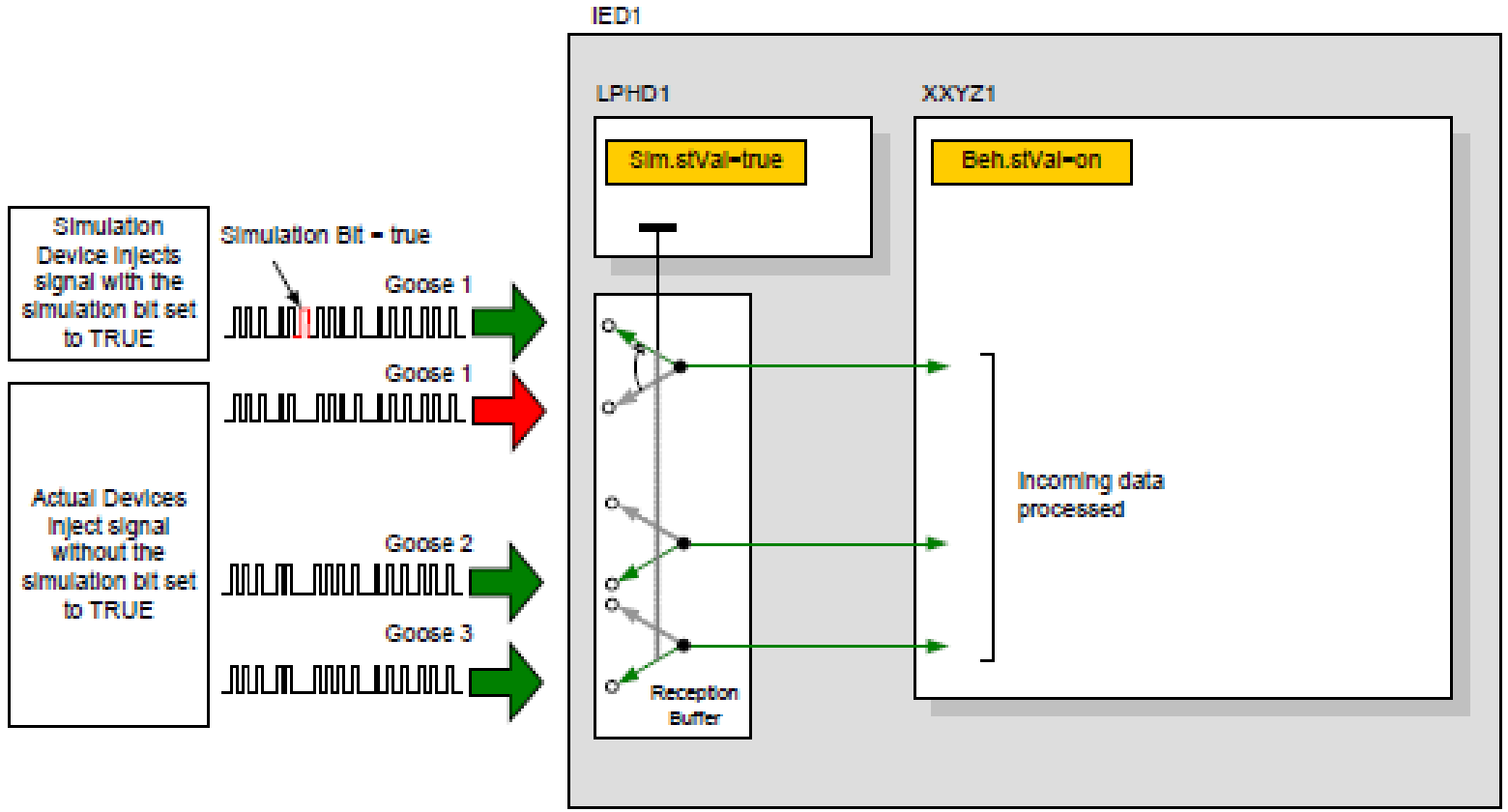
Testing and Simulated Signals

- In order to carry out functional, commissioning or maintenance tests, a communications network-based SAS that supports testing functions should offer some of the following facilities:
  - at the IED level, the option of receiving multicast simulation signals instead of actual signals (see 7.8.2);
  - at the LN (function) level, the option of receiving test input signals instead of actual signals (see 7.8.3);
  - at the LN (function) level, the option of setting a function or a group of functions of the system in test mode (see 7.8.4).

Multicast Simulation Signals

- Example of an IED (IED1) receiving simultaneously simulation and actual signals

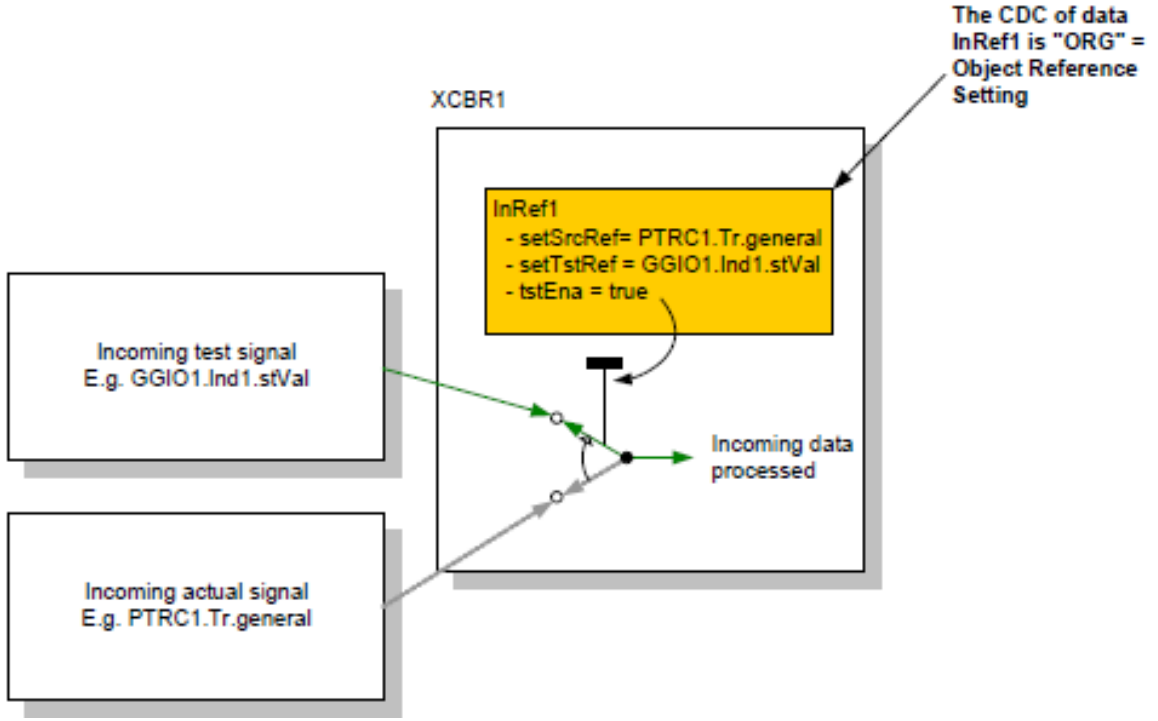
To allow the IED1 to process the simulated Goose1 message instead of the actual Goose 1 message, the data Sim.stVal in the LN LPHD1 shall be set to TRUE.



Input Signals Used For Testing

- Each LN may have one or several data named InRef1 to InRefn and used as input signals to the function represented by the LN

- The data can be used to switch between actual and test incoming signals as shown in the example.
- This change is made by setting the value of the attribute InRef1.tstEna to TRUE.

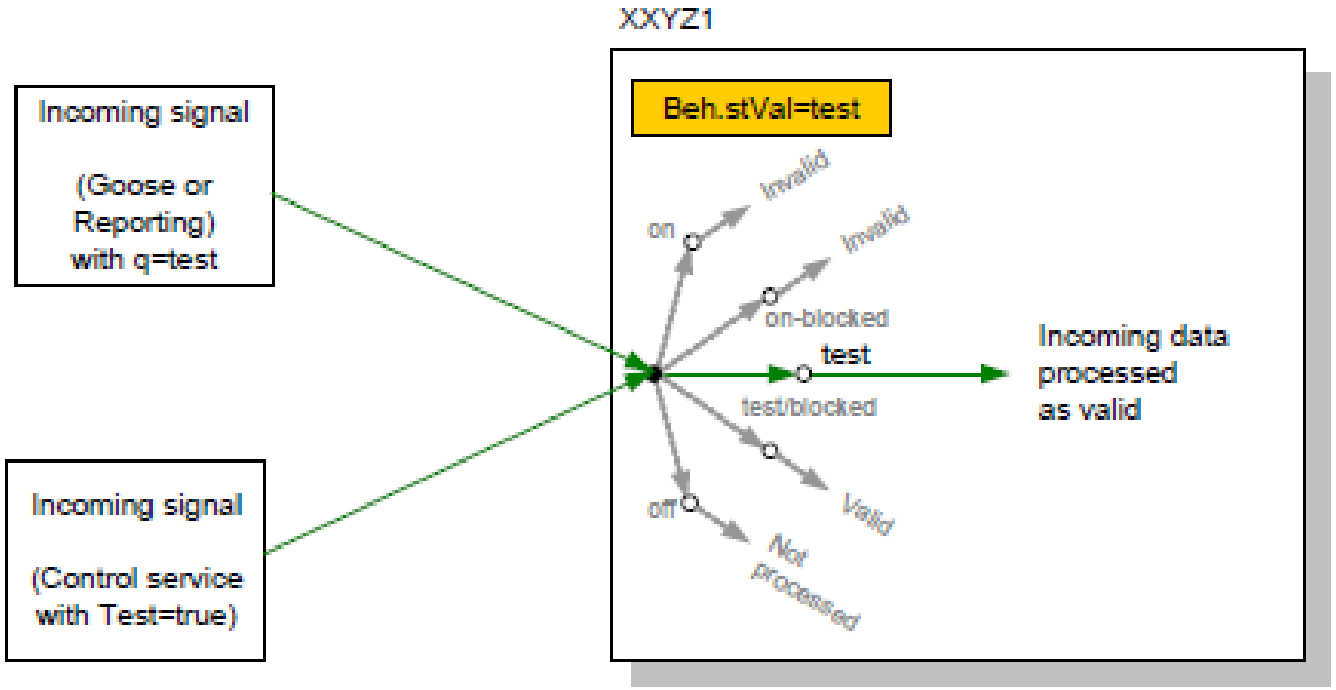


Test Mode

- Example of a function (LN XXYZ1) in test mode. In order to make the function accept an incoming signal as valid for testing purposes, the following conditions shall be observed:

  - The mode of the function (Beh.stval) being part of the test shall be set to ‘test’ or ‘test/blocked’,
  - In case of Goose or reporting services, the quality value of the incoming data shall be ‘test’,
  - In case of control services, the control service parameter Test value shall be TRUE.

Otherwise, the signal will be treated as invalid. The detailed requirements for the different states of Mod/Beh can be found in IEC 61850-7-4.



Subscription Monitoring (LGOS and LSVS)

- The LGOS and LSVS logical nodes may be used to monitor subscription states to GOOSE or SV signals. They contain mandatory information like status of the subscription (active, not active) and other optional information e.g. the source GOOSE or SV control block identification.
- The root LD LPHD.Sim.StVal is used to switch the ability of the DUT to accept real or simulated test signals. The LGOS or LSVS will indicate the state of the incoming signals.
  - For example if LPHD.Sim.StVal=true and there is a SV telegram with the simulation flag set=true then LSVS1.St.stVal=true and LSVS1.SimSt.StVal=true

Extended Logging Function

- Some applications require the recording of sequential events whose events are not only defined by the data that triggered the event but also by other useful information that needs to be captured simultaneously when the event occurred. The function used to set the additional data to be captured is represented by the LN GLOG: Generic Log.
  - There shall be only one Log per LN GLOG

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THANK YOU

QUESTIONS?