

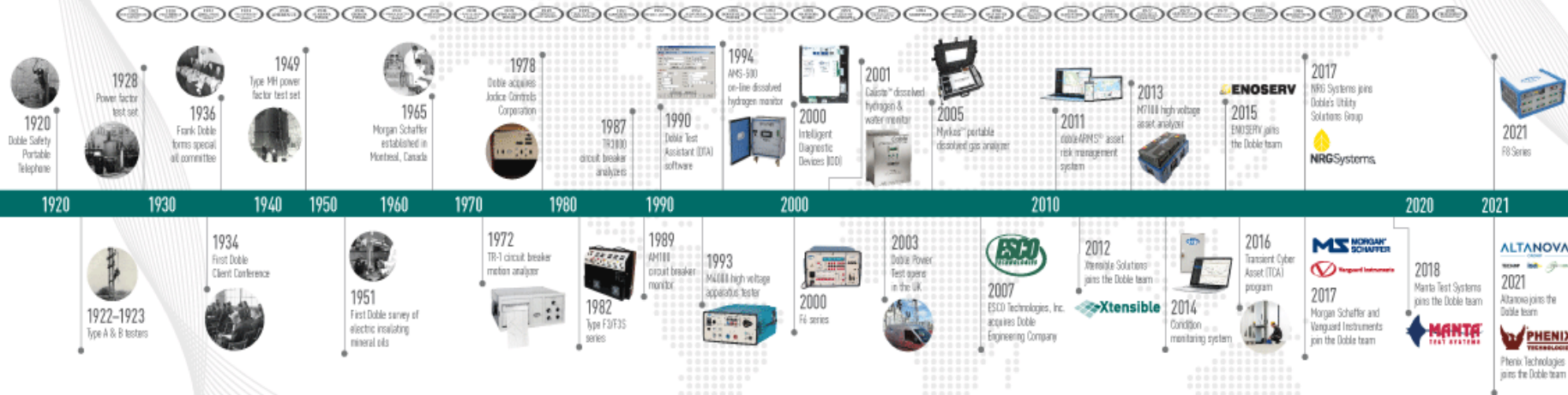
# IEC 61850 Standard-based Protection Applications Testing and Network Analysis

Jose Ruiz | Principal Technical Application Engineer | Doble Engineering



# Who is Doble Engineering?

## 100 YEARS OF SERVICE TO THE ELECTRIC UTILITY INDUSTRY

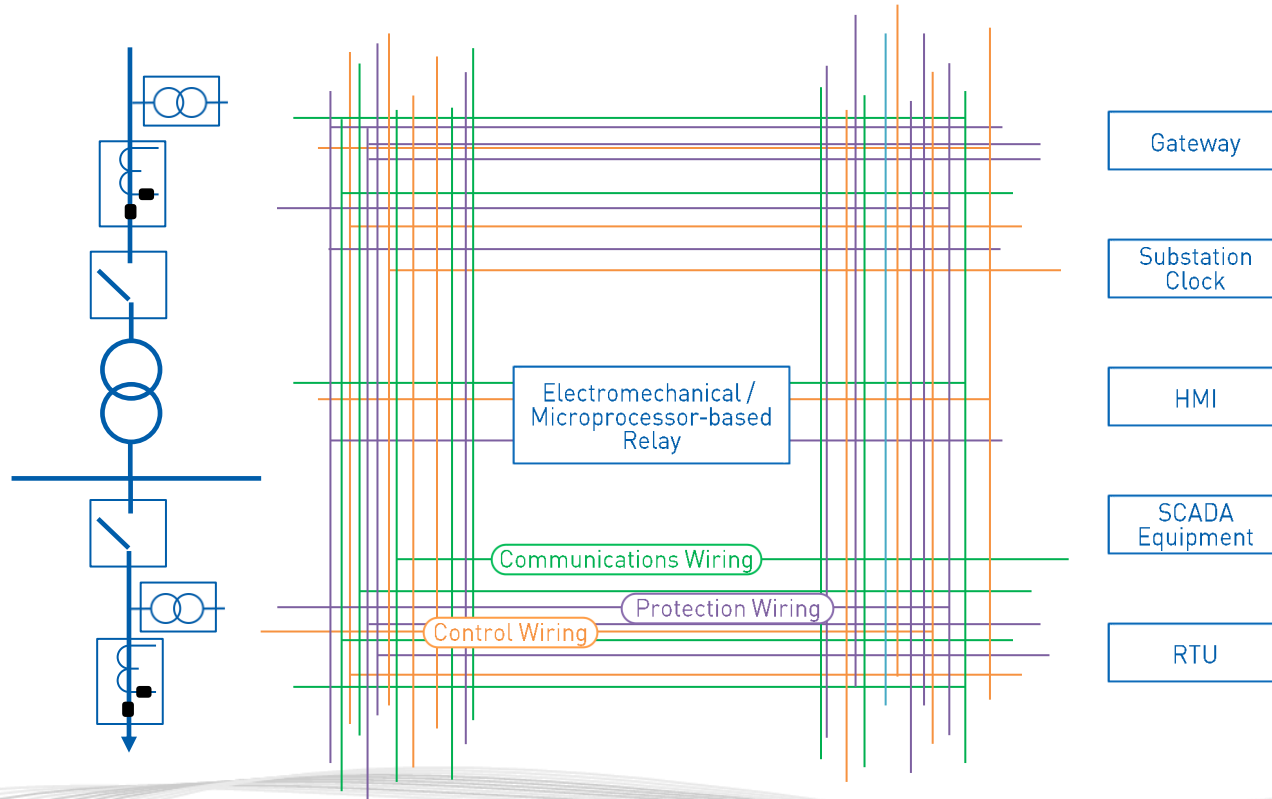




# What is IEC 61850?

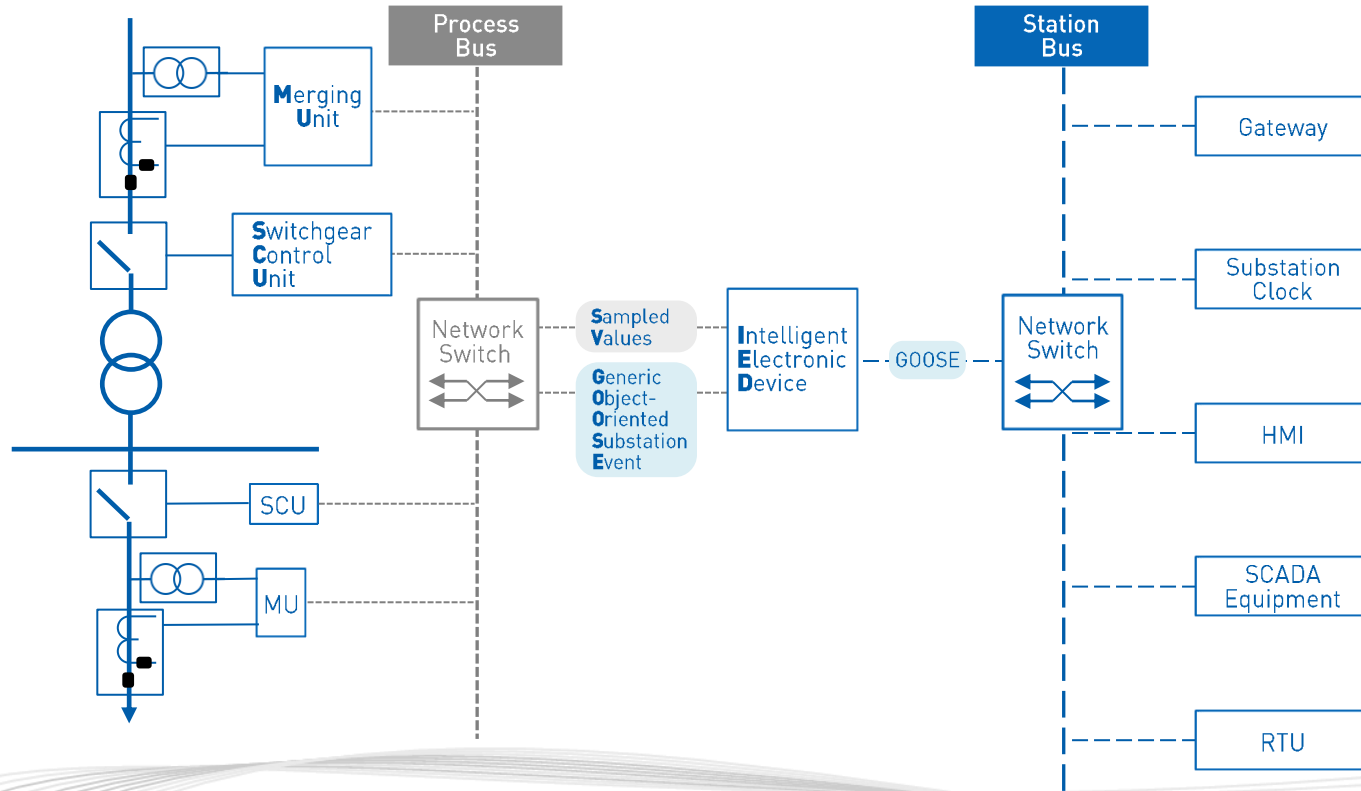


# Conventional Protection & Control

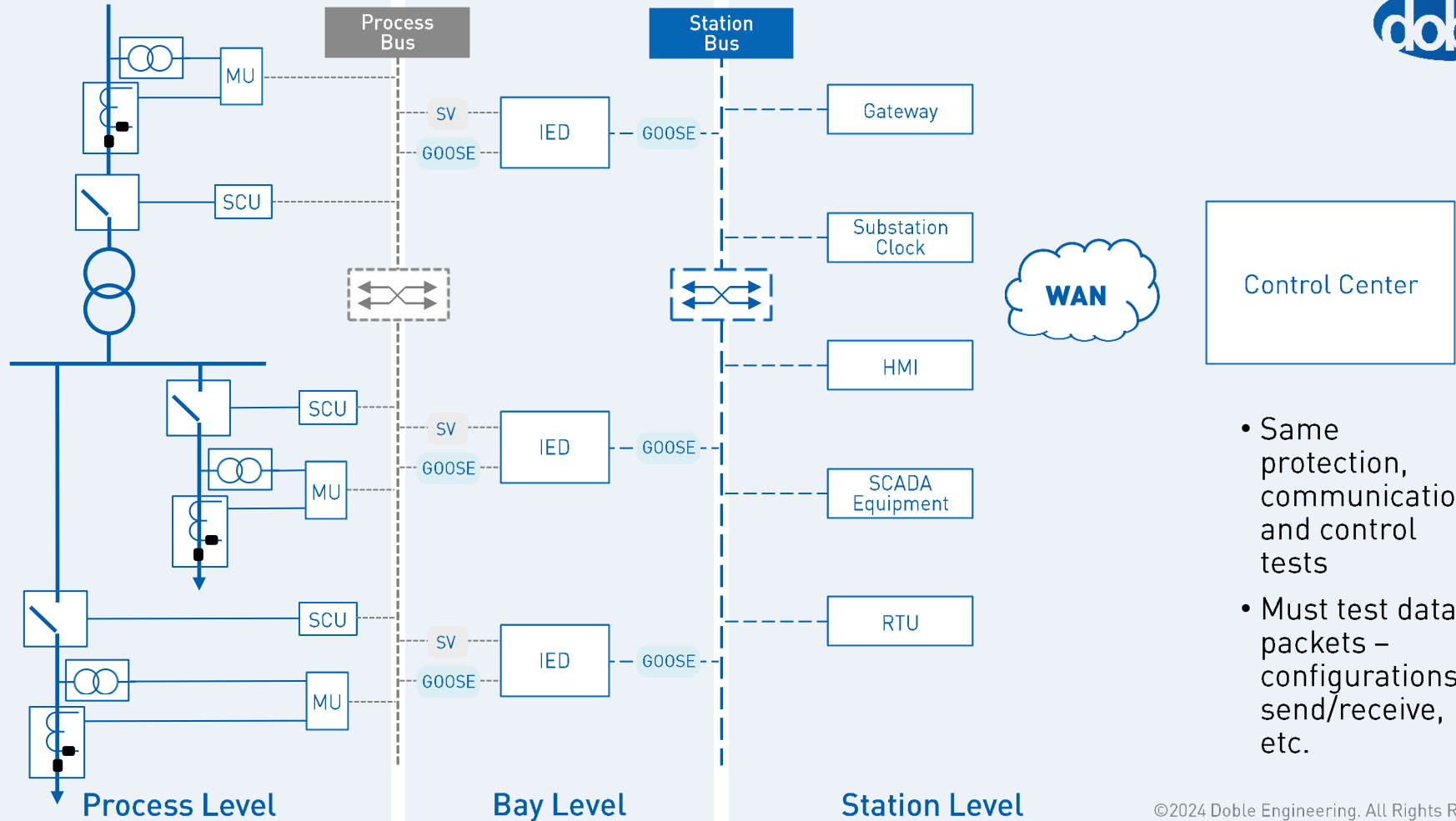


- Expensive and complex wiring
- Numerous point-to-point checks when commissioning
- Physical and proprietary constraints
- Many variables station-to-station

# Digital P&C Based on IEC 61850 Standard

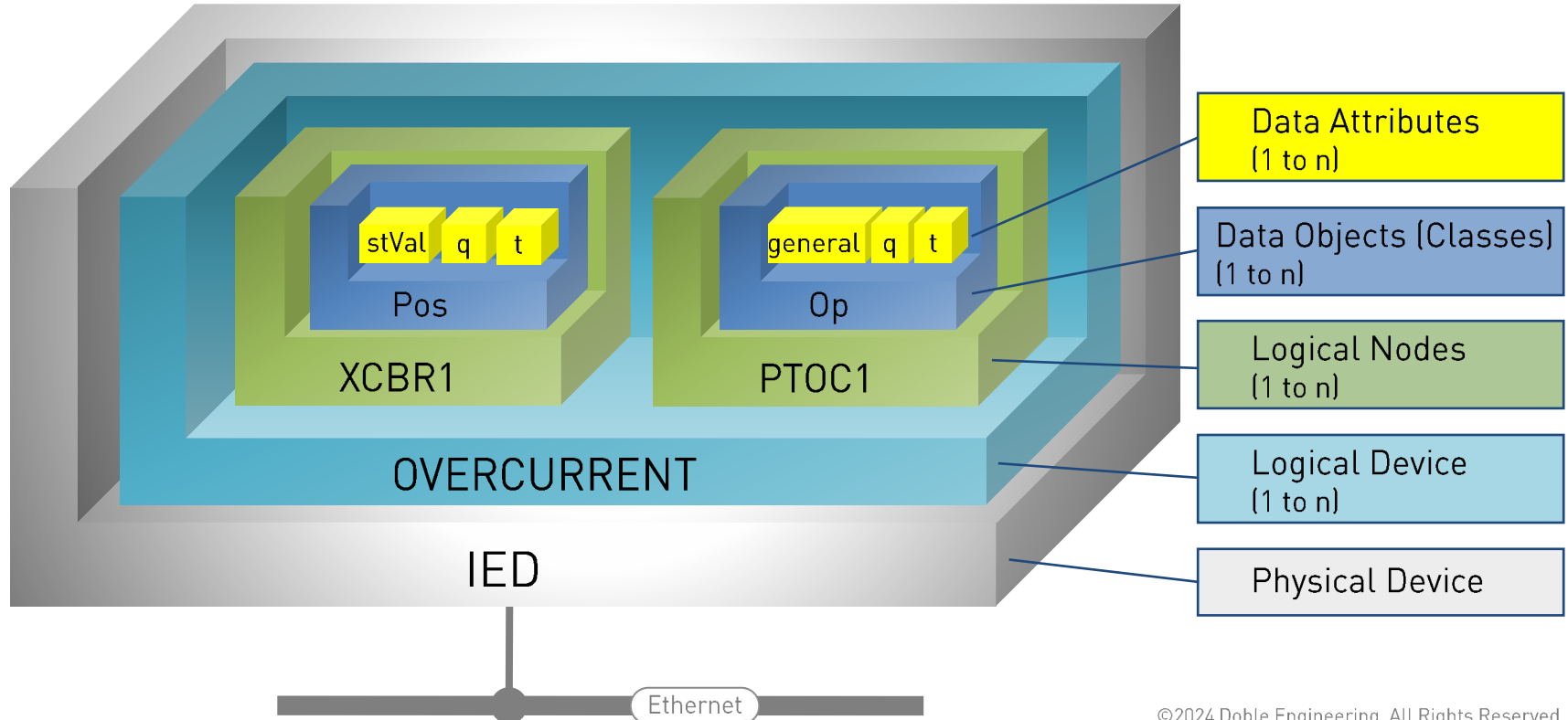


- Simplified connections
- Fewer on-site commissioning steps
- Virtually limitless possibilities
- Promotes standardization



- Same protection, communication, and control tests
- Must test data packets – configurations, send/receive, etc.

# Packet Structure



# Hierarchical View

Physical Device has an application specific name

Logical Nodes: prefix + **Logical Node Class** name (*standardized*) + instance-Id. Whole LN name can be vendor product specific or application specific.

OVERCURRENT/PTOC1.Op.general

IED: Fdr1\_Prot

LD: MEASUREMENTS

LD: **OVERCURRENT**

LN: XCBR1

LN: **PTOC1**

DO: Str

DO: **Op**

DA: general

DA: q

DA: t

A Logical Device is a grouping of related functions. No specific arrangement rule. Names are vendor product specific or application specific.

Data Object / Data Class names are standardized

Data Attribute names are standardized



# Data Attribute Types

- **Boolean** [ true (1) or false (0)]
- **Dbpos** (Double bit position, also defined a Coded Enum below)

Enum Value	Bit Pair	Usual meaning (ex. for CB)
0	0 0	Intermediate state
1	0 1	Off (or Open)
2	1 0	On (or Closed)
3	1 1	Bad state

- **Integer**
- **Floating point**
- **Enumerated**
- **Timestamp**
- **Visible string**
- **etc.**

# Constructed Data Attribute Types

- Quality

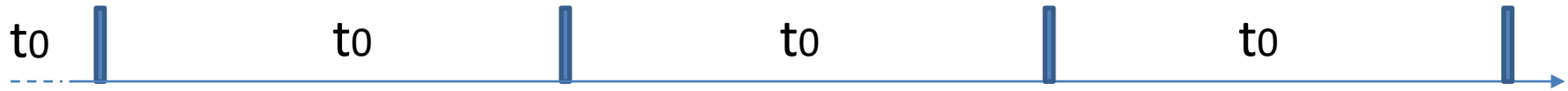
Quality type definition		
Attribute name	Attribute type	Value/Value range
	PACKED LIST	
validity	CODED ENUM	good   invalid   reserved   questionable
detailQual	PACKED LIST	
overflow	BOOLEAN	DEFAULT FALSE
outOfRange	BOOLEAN	DEFAULT FALSE
badReference	BOOLEAN	DEFAULT FALSE
oscillatory	BOOLEAN	DEFAULT FALSE
failure	BOOLEAN	DEFAULT FALSE
oldData	BOOLEAN	DEFAULT FALSE
inconsistent	BOOLEAN	DEFAULT FALSE
inaccurate	BOOLEAN	DEFAULT FALSE
source	CODED ENUM	process   substituted DEFAULT process
test	BOOLEAN	DEFAULT FALSE
operatorBlocked	BOOLEAN	DEFAULT FALSE

Published by  
IEDs and seen  
by sniffers as  
a string of  
**13 bits**

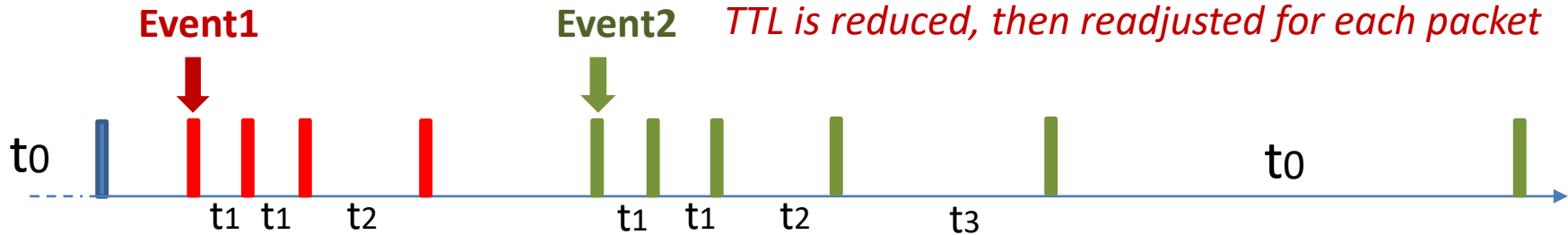
SCL File Types		
SSD	System Specification Description	System equipment connections, functions, logical nodes.
ICD	IED Capability Description	Data model and items supported by an IED.
IID	Instantiated IED Description	Instantiated data and published or transmitted messages.
CID	Configured IED Description	Actual configuration (instantiated objects/data, published messages, and IEDs/messages and data subscribed to.
SCD	System Configuration Description	Actual configuration of entire system or sub-system (multiple IEDs).
SED	System Exchange Description	Messages and datasets that need to be exchanged between projects.

# GOOSE Retransmission

- Periodic maximum retransmission (heartbeat) of GOOSE with time  $t_0$
- Time to live (TTL) is initially time  $t_0$ ; Loss of packet can be detected



- On a data change (Event1), GOOSE is published immediately and rapidly at gradually increasing time  $t_1, t_2, t_3$  until it reaches max. time  $t_0$



- On any new data change (Event2), GOOSE rapid publishing is restarted until it reaches time max time  $t_0$

# Anatomy of GOOSE Messages

Substation
F6 Input
F6 Output
PC GSE Simulator
Subscription Mapping
Notes

View, discover or create GSE messages
☐ Allow addition of scanned messages with new GSE CB Ref

	IED Name	LD Name	GSE Control Block Reference	Dataset Name	GSE ID	VLAN		Simulate Bit	Show Live Data	Enable PC Simulation	Select all GN	Select all GP	Quality Value	Delete
						ID	Priority							
...	LINE1	System	LINE1System/LLN0\$GO\$gcb01	ds1_Protection	Go1_Pro	0	4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Select	X
...	LINE1	System	LINE1System/LLN0\$GO\$gcb02	ds2_CBR	Go2_CBR									
...	LINE1	System	LINE1System/LLN0\$GO\$gcb03	ds3_Supv	Go3_Supervision									
...	PRO_LINE12	LD0	PRO_LINE12LD0/LLN0\$GO\$GCB_S1_PROT	DS_PROT	PRO_LINE11LD0/LLN0.GCB									
...	PRO_LINE12	LD0	PRO_LINE12LD0/LLN0\$GO\$GCB_S3_PROT	DS_PROT	PRO_LINE11LD0/LLN0.GCB									
...	PRO_LINE12	LD0	PRO_LINE12LD0/LLN0\$GO\$GCB_S1_TEST	DS_TEST	PRO_LINE11LD0/LLN0.GCB									
...	PRO_LINE12	LD0	PRO_LINE12LD0/LLN0\$GO\$GCB_S3_TEST	DS_TEST	PRO_LINE11LD0/LLN0.GCB									
...	PRO_LINE11	LD0	PRO_LINE11LD0/LLN0\$GO\$GCB_S1_PROT	DS_PROT	PRO_LINE11LD0/LLN0.GCB									

View GSE Configuration Details
 Compare IEDs

Dataset items

Dataset Items	Data type	Default Value	Details from SCL file
1 - general	Boolean	0	LINE1.ProtDis.DisPDIS1.Op.general
2 - q	Quality	G-00000000-P-00	LINE1.ProtDis.DisPDIS1.Op.q(ST)
3 - general	Boolean	0	LINE1.ProtDis.DisPDIS2.Op.general
4 - q	Quality	G-00000000-P-00	LINE1.ProtDis.DisPDIS2.Op.q(ST)
DisPTRC3.ST.Op			
5 - general	Boolean	0	LINE1.ProtDis.DisPTRC3.Op.general(ST)
6 - q	Quality	G-00000000-P-00	LINE1.ProtDis.DisPTRC3.Op.q(ST)
7 - t	UTCTimeStamp	2021/10/07 19:15:57.068 1F	LINE1.ProtDis.DisPTRC3.Op.t(ST)

**GSE Type**

GOOSE

**IED Name**

LINE1

**LD Name**

System

**GSE CB Name**

gcb01

**GSE ID**

Go1\_Pro

**Dataset Name**

ds1\_Protection

**Config Rev**

1

**Needs Commissioning**

☐

**Simulate Bit**

☐

**Source MAC Address**

AB-CD-EF-00-00-00 [Edit MAC Address](#)

**Dest. MAC Address**

01-0C-CD-01-00-00

**App ID**

1 ☒ Hexadecimal ☐ Decimal

**VLAN ID**

0 ☒ Hexadecimal (0-FFF) ☐ Decimal (0-4095)

**VLAN Priority**

4

**GSE CB Ref.**

LINE1System/LLN0\$GO\$gcb01

**Dataset Ref.**

LINE1System/LLN0\$ds1\_Protection

**Retransmission**

Minimum time: 20 ms

Interval multiplier: 2

Maximum time: 1000 ms

Save
 Cancel



# Process Bus

- Sampled Values (SV)
  - Stand-alone Merging Units (SAMU)
    - Used with Conventional CTs and VTs to convert analog values to Sampled Values
  - Non-conventional Instrument Transformers (NCIT)
- Process digital signals
  - GOOSE signals
    - Handled thru I/O units or SCUs (switchgear control unit)
  - Client-Server (MMS)

Combined in one device: Process Interface unit (PIU): MU + SCU

# Sampled Values - UCAIUG 9-2 LE

## Implementation Guideline

- Purpose of implementation guideline
  - Support fast market introduction of the standard
  - Define a subset to facilitate first implementations
- Logical device **merging unit** name: **xxxxMU<sup>nn</sup>yy**
  - **xxxx** : alphanumeric name (up to 28 characters)
  - **MU** : fixed, stands for merging unit
  - **nn** : merging unit number
  - **yy** : 01 for protection (80 samples/cy), 02 for metering (256 samples/cy)
  - Example: **LINE1MU0401**
- Fixed dataset
  - 4 currents and 4 voltages
  - Phases A, B, C and neutral

# Sampled Values – New Standard

IEC 61850-9-2 Edition 2 and IEC 61869-9 (2016 April)

- Naming is more flexible
- Preferred variants: datasets can have a single quantity of voltage or current up to a maximum of 24 (such as 8 voltages and 16 currents)
- Sample rate of 4800 samples/s (*not samples/cycle*) for protection for all nominal frequencies
- Existing 9-2 LE is fully supported as a legacy variant
- Time synchronization:
  - IEC 61588 (PTP, also known as IEEE 1588), 1 PPS is supported

# Testing IEC 61850 Standard-Based PACS



# Testing – Isolation Challenges



Conventional test switch



*No visible  
physical switches*



IEC 61850 Ethernet connection



## Testing – Isolation Challenges (2)

- Unplugging Ethernet connectors to devices for isolation is not allowed. It causes loss of messages and alarms in the subscribers.
- Test signals (SV and GOOSE) are seen by DUT as well as devices in normal service – a source of confusion and **major security concern**
- “**Virtual switches**” replace conventional physical test switches for **isolating device under test (DUT)** and the **injected test signals** from the rest of the system in normal service

# Test Features – **Isolation** during Maintenance

**Test signals** injected by test set should be:

- **Accepted only** by Devices (*IEDs or Logical devices*) under test (**DUT**)
- **Ignored** by devices that are in **normal service**

## **Simulation:**

- Test set publishes SV and GOOSE messages with **Simulation flag = true**
- **DUT set to Simulation mode** will process messages with Simulation flag = true
- Devices in **normal service** (Simulation not set) will ignore or **not process** simulated messages

## **Output Signals** of DUT

- Outputs signals should be **ignored** by other devices that are in **normal service**
- Hard-wired (physical) outputs of the DUT must be **blocked** from operating on the process

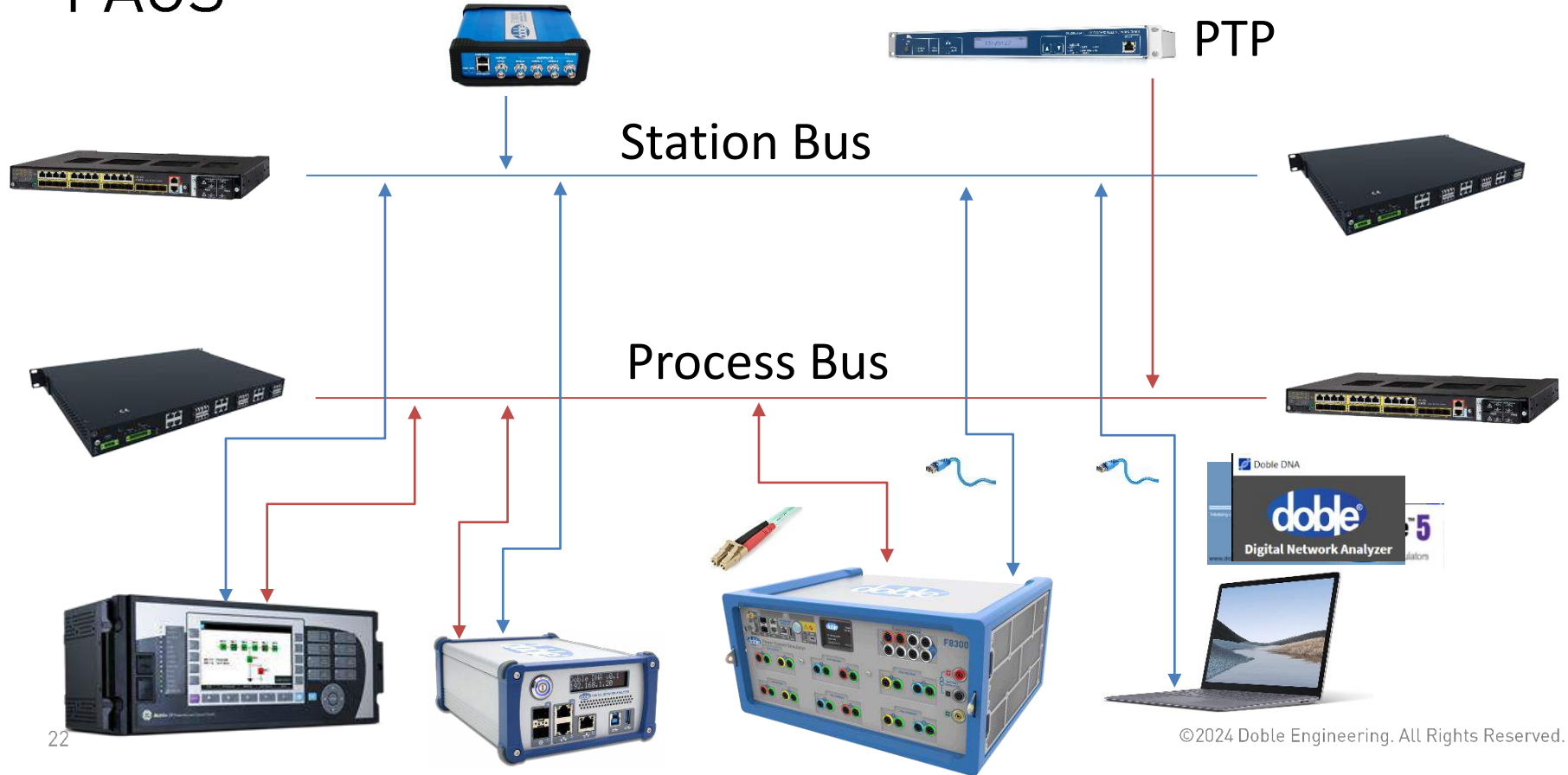
## **Mode/Behavior:** – On, Test, Test/blocked

- GOOSE outputs of DUT (Beh=Test) identified with **q.test=true**
  - Devices in **normal service** (Beh=On) **ignore** (or **process as Invalid**) signals with q.test=true
  - Devices in test mode process **all** signals
- Test/blocked mode: Physical outputs **blocked**

# Doble Solutions



# Doble Solutions for Testing IEC 61850-based PACS



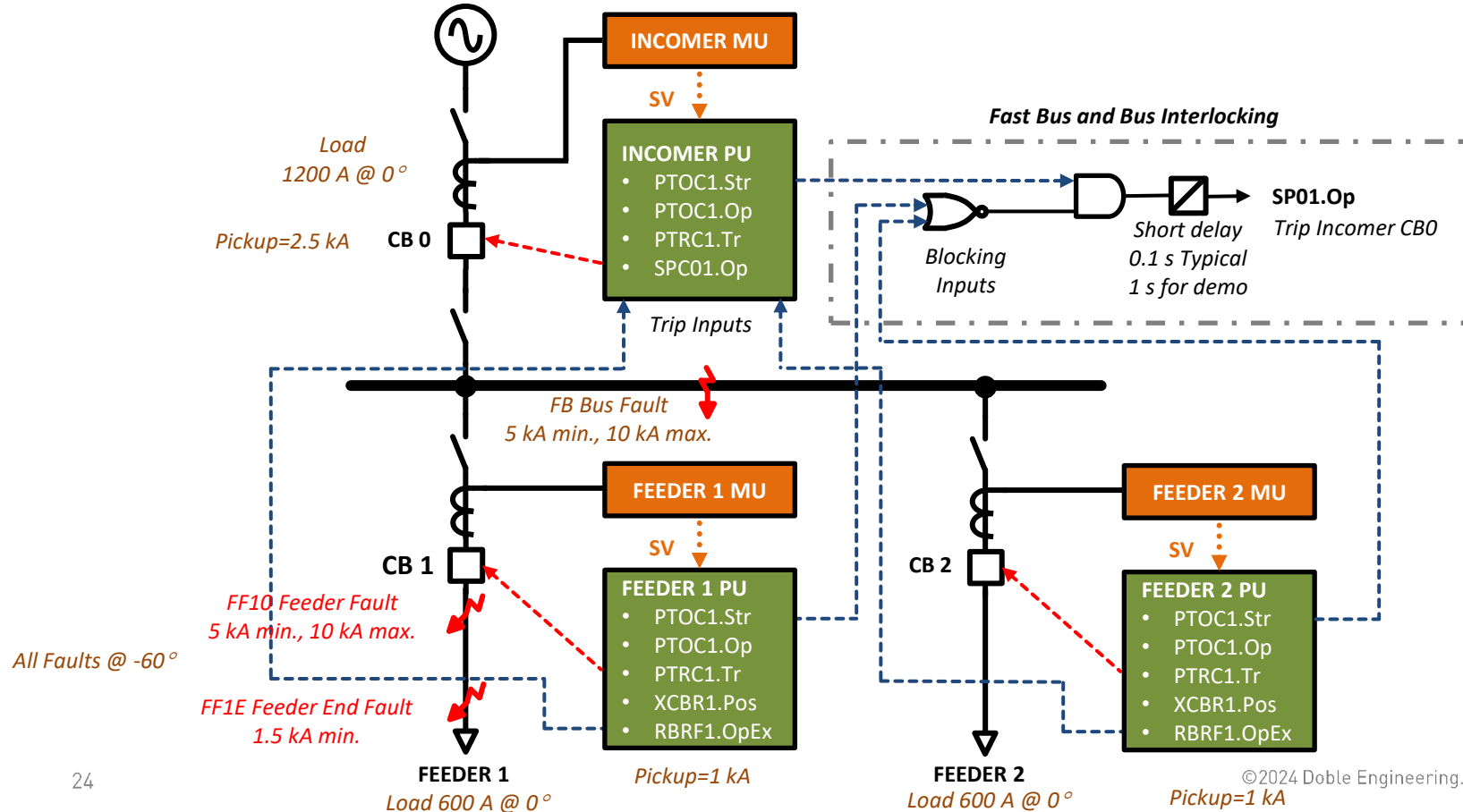


# Testing Example

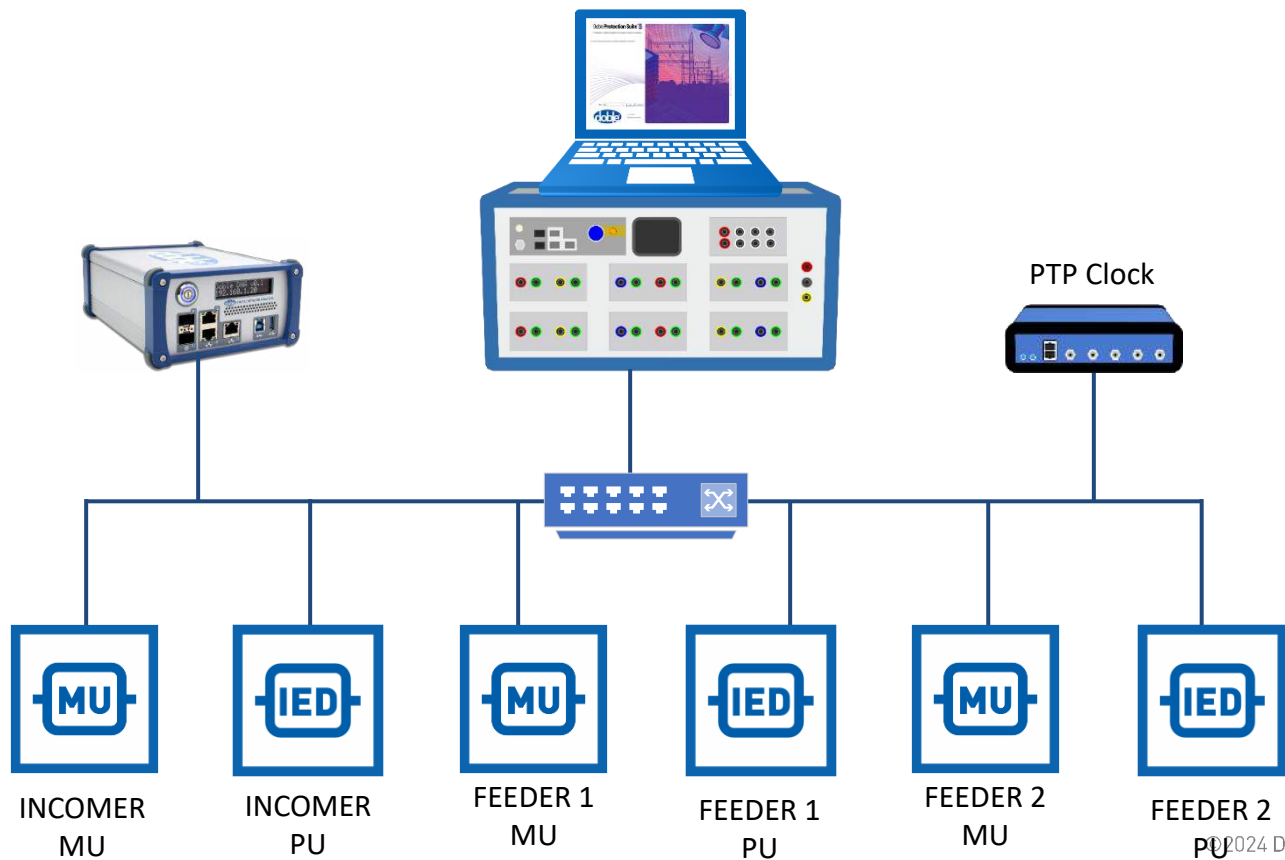




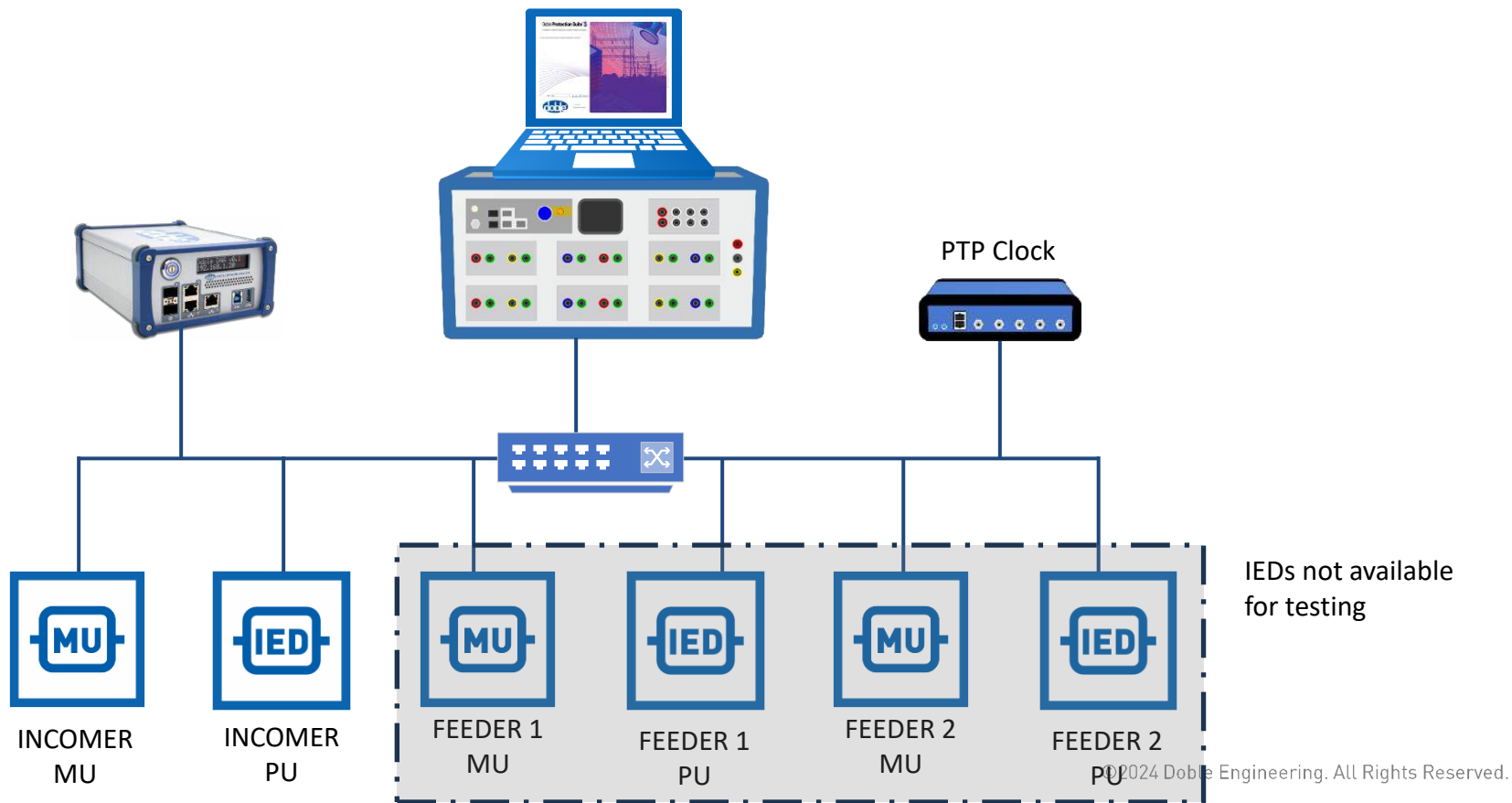
# Reverse Blocking Bus Protection Scheme



# Network Configuration



# Network Configuration



# Time for a Demonstration

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# Questions?



The examples presented in this webinar were sponsored by:



Protection Suite software  
+  
F8000-series Power System Simulators

