Substation Automation Systems
IEC 61850 standard

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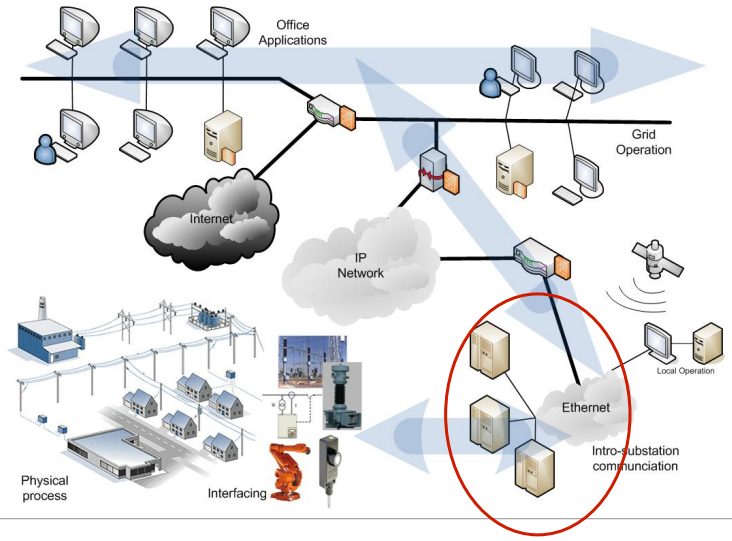
Course map



Outline of the Lecture

- Recap of modern substation architectures
  - IEC 61850 substation
  - Purpose and scope of IEC 61850
- IEC 61850 Information Model
- Specification and configuration
- Substation communication
  - Very brief introduction (more coming next week)

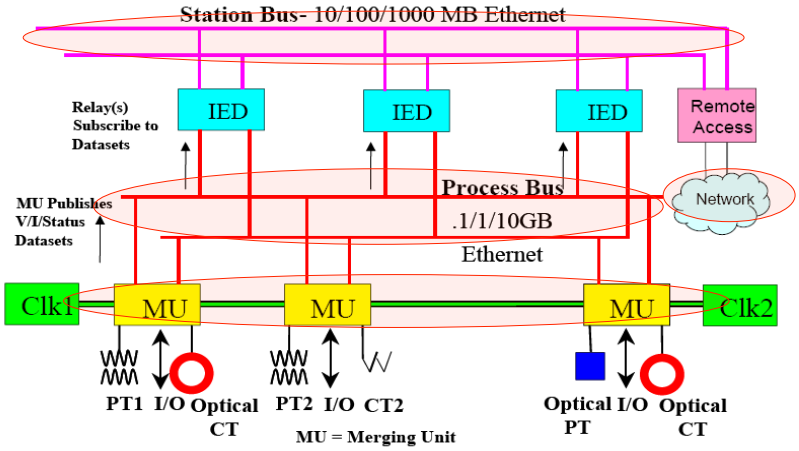
Recap

Common components

- **Remote Terminal Unit**
  - Telemetry and remote control device
- **Intelligent Electronic Device(s)**
  - Implements functions
- **Bay controller**
  - controls all devices related to a single bay
- **Human Machine Interface**
  - Operator console for local control/configuration
- **Communication bus(es)**
  - Connection between devices
- **Upwards communication interface.**
  - To SCADA

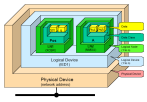
Substation architectures

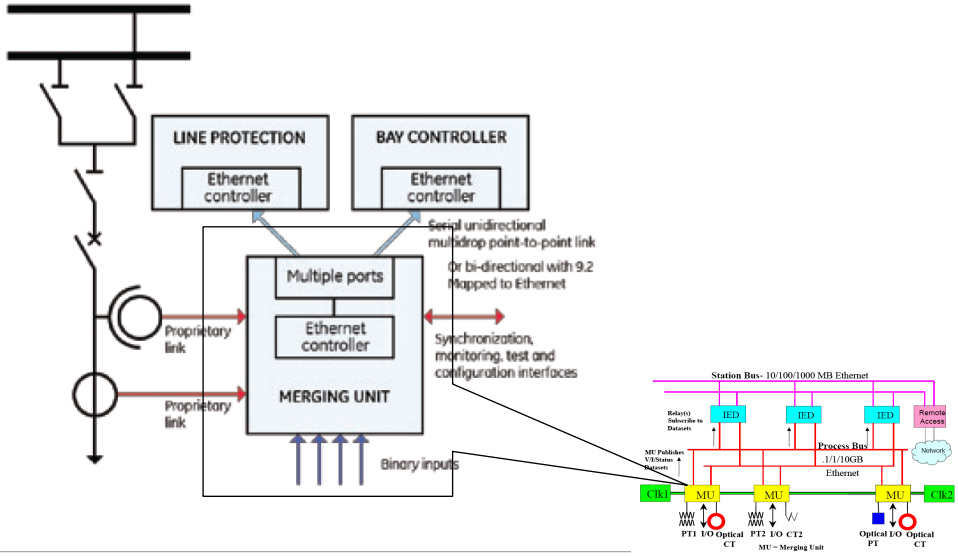
IEC 61850 substation



Substation architectures

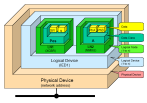
The Merging Unit





Purpose and Scope of IEC 61850

Objectives

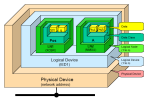


The 61850 standard was developed to:

- Address the need for a **more structured approach** to design of Substation Automation Systems
- **Separate Data model** from method of **communication**
- Utilise new technologies (**Ethernet, TCP/IP**)
- Enable **vendor independence**
- **Simplify** system configuration
- Enable **sharing of measurement** among devices

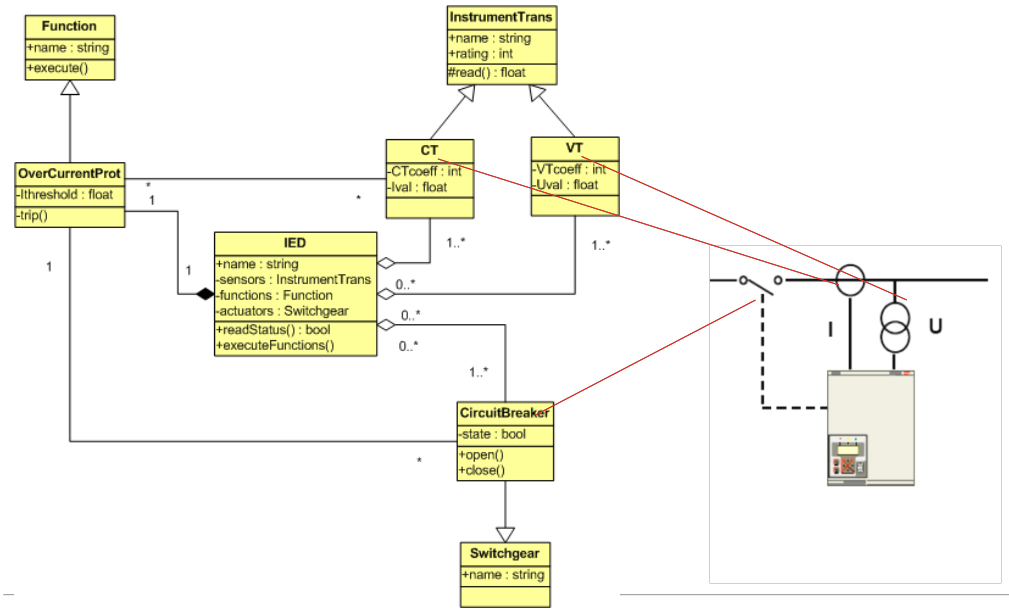
Purpose and Scope of IEC 61850

How is this achieved?



- **Model information about the real world**
  - Status, measurements, settings
  - Configuration of system
    - Single-line diagram
    - Function related information
- **Defines when to exchange values**
  - Configuration of IED
- **Defines how to exchange values**
  - Configuration of IED
- **Describe the recipient of the values**
  - Configuration of IED
- **Describe who to receive values from**
  - Configuration of IED

Information Models



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IEC 61850 Information Model

Modelling a substation

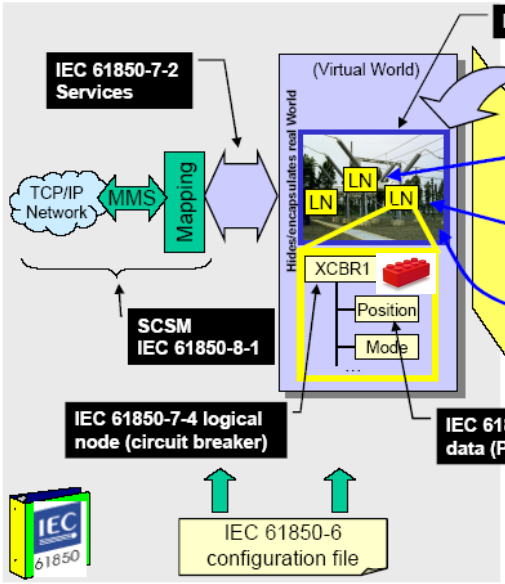
- We would like to have some kind of standardized building-block for functionality
- Enter the Logical Node (LN)…

IEC 61850 Information Model

- Modelling a substation
- Component hierarchy
- IEC 61850-8-1 object name
- Logical Node (LN) groups
- Logical Node (LN) examples
- Assigning Logical Nodes

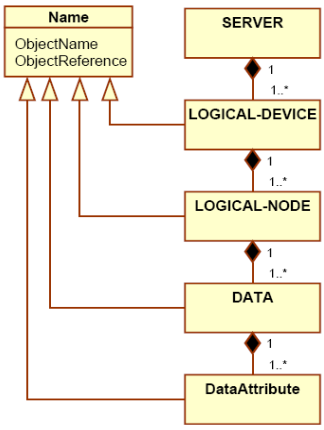
IEC 61850 Information Model

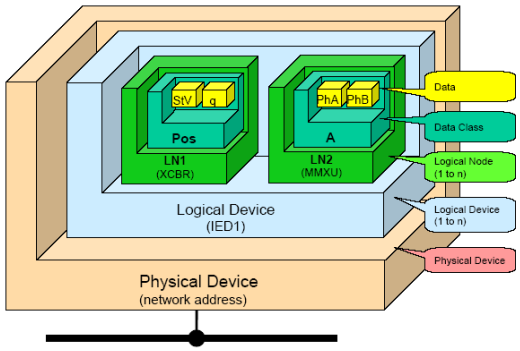
Modelling a substation



IEC 61850 Information Model

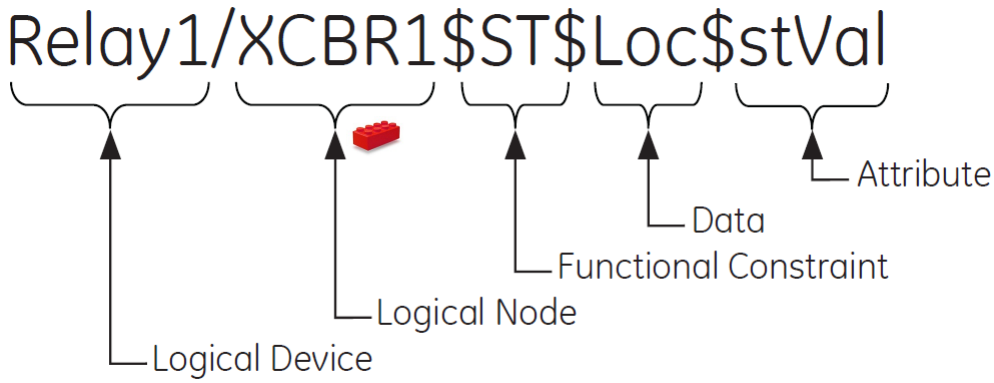
Component hierarchy





IEC 61850 Information Model

IEC 61850-8-1 object name



IEC 61850 Information Model

Logical Nodes - Groups

Name	Description
Axxx	Automatic Control (4). ATCC (tap changer), AVCO (volt. ctrl.), etc.
Cxxx	Supervisory Control (5). CILO (Interlocking), CSWI (switch ctrl), etc.
Gxxx	Generic Functions (3). GGIO (generic I/O), etc.
Ixxx	Interfacing/Archiving (4). IARC (archive), IHMI (HMI), etc.
Lxxx	System Logical Nodes (2). LLN0 (common), LPHD (Physical Device)
Mxxx	Metering & Measurement (8). MMXU (meas.), MMTR (meter.), etc.
Pxxx	Protection (28). PDIF, PIOC, PDIS, PTOV, PTOH, PTOC, etc.
Rxxx	Protection Related (10). RREC (auto reclosing), RDRE (disturbance)..
Sxxx	Sensors, Monitoring (4). SARC (archs), SPDC (partial discharge), etc.
Txxx	Instrument Transformer (2). TCTR (current), TVTR (voltage)
Xxxx	Switchgear (2). XCBR (breaker), XCSW (switch)
Yxxx	Power Transformer (4). YPTR (transformer), YPSH (shunt), etc.
Zxxx	Other Equipment (15). ZCAP (cap ctrl), ZMOT (motor), etc.
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)

IEC 61850 Information Model

Logical Nodes – Example XCBR

XCBR 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
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

IEC 61850 Information Model

Logical Nodes – Other examples

- **TVTR** – Voltage transformer
- **TCTR** – Current transformer
- **MMXU** – Measurement
- **XCBR** – Circuit Breaker
- **PDIF** – Differential Protection
- **PDIS** – Distance Protection

IEC 61850 Information Model

Logical Nodes – Example MMXU - Measurement

MMXU 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
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

IEC 61850 Information Model

Logical Nodes – Example TVTR – Voltage Transformer

TVTR 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		O
EEName	DPL	External equipment name plate		O
OpTmh	INS	Operation time		O
Measured values				
Vol	SAV	Voltage (sampled value)		M
Status Information				
FuFail	SPS	TVTR fuse failure		O
Settings				
VRtg	ASG	Rated Voltage		O
HzRtg	ASG	Rated frequency		O
Rat	ASG	Winding ratio of external voltage transformer (transducer) if applicable		O
Cor	ASG	Voltage phasor magnitude correction of external voltage transformer		O
AngCor	ASG	Voltage phasor angle correction of external voltage transformer		O

IEC 61850 Information Model

Logical Nodes – Example TCTR – Current Transformer

TCTR 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		O
EEName	DPL	External equipment name plate		O
OpTmh	INS	Operation time		O
Measured values				
Amp	SAV	Current (Sampled value)		M
Settings				
ARtg	ASG	Rated Current		O
HzRtg	ASG	Rated Frequency		O
Rat	ASG	Winding ratio of an external current transformer (transducer) if applicable		O
Cor	ASG	Current phasor magnitude correction of an external current transformer		O
AngCor	ASG	Current phasor angle correction of an external current transformer		O

IEC 61850 Information Model

Logical Nodes – Example XCBR – Circuit Breaker

XCBR class				
Attribute Name	**Attr. Type**	**Explanation**	**T**	**M/O**
LNName		Shall be inherited from Logical-Node Class (s 1850-7-2)		
Data				
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

IEC 61850 Information Model

Logical Nodes – Example PTOC – Overcurrent Protection

PTOC 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
OpCntRs	INC	Resetable operation counter		O
Status Information				
Str	ACD	Start		M
Op	ACT	Operate	T	M
TmASt	CSD	Active curve characteristic		O
Settings				
TmACrv	CURVE	Operating Curve Type		O
StrVal	ASG	Start Value		O
TmMult	ASG	Time Dial Multiplier		O
MinOpTmms	ING	Minimum Operate Time		O
MaxOpTmms	ING	Maximum Operate Time		O
OpDlTmms	ING	Operate Delay Time		O
TypRsCrv	ING	Type of Reset Curve		O
RsDlTmms	ING	Reset Delay Time		O
DirMod	ING	Directional Mode		O

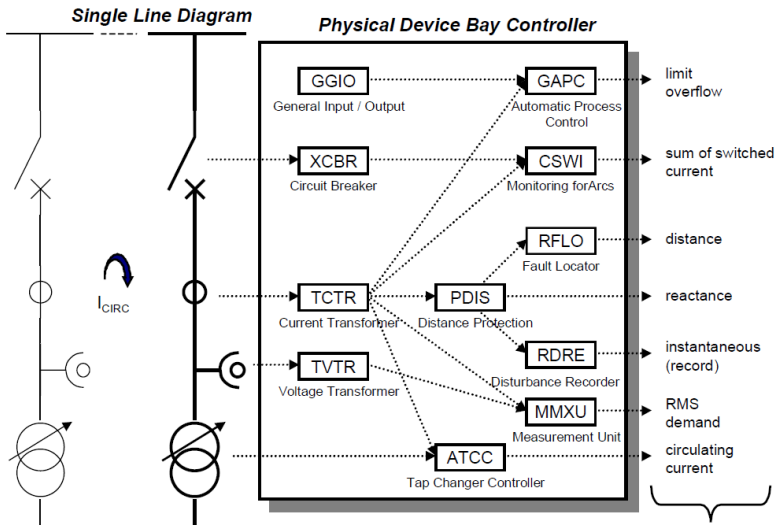
IEC 61850 Information Model

Logical Nodes – Example PDIS – Distance Protection

PDIS 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
OpCntRs	INC	Resetable operation counter		O
Status Information				
Str	ACD	Start		M
Op	ACT	Operate	T	M
Settings				
PoRch	ASG	Polar Reach is the diameter of the Mho diagram		O
PhStr	ASG	Phase Start Value		O
GndStr	ASG	Ground Start Value		O
DirMod	ING	Directional Mode		O
PctRch	ASG	Percent Reach		O
Ofs	ASG	Offset		O
PctOfs	ASG	Percent Offset		O
RisLod	ASG	Resistive reach for load area		O
AngLod	ASG	Angle for load area		O
TmDlMod	SPG	Operate Time Delay Mode		O
OpDlTmms	ING	Operate Time Delay		O
PhDlMod	SPG	Operate Time Delay Multiphase Mode		O
PhDlTmms	ING	Operate Time Delay for Multiphase Faults		O
GndDlMod	SPG	Operate Time Delay for Single Phase Ground Mode		O
GndDlTmms	ING	Operate Time Delay for single phase ground faults		O

IEC 61850 Information Model

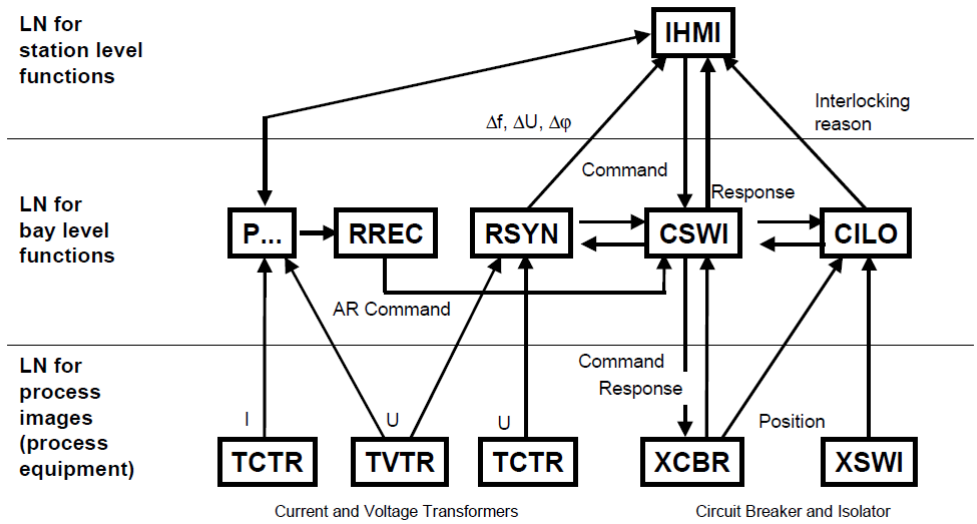
Logical Nodes – Example



examples for some current related data

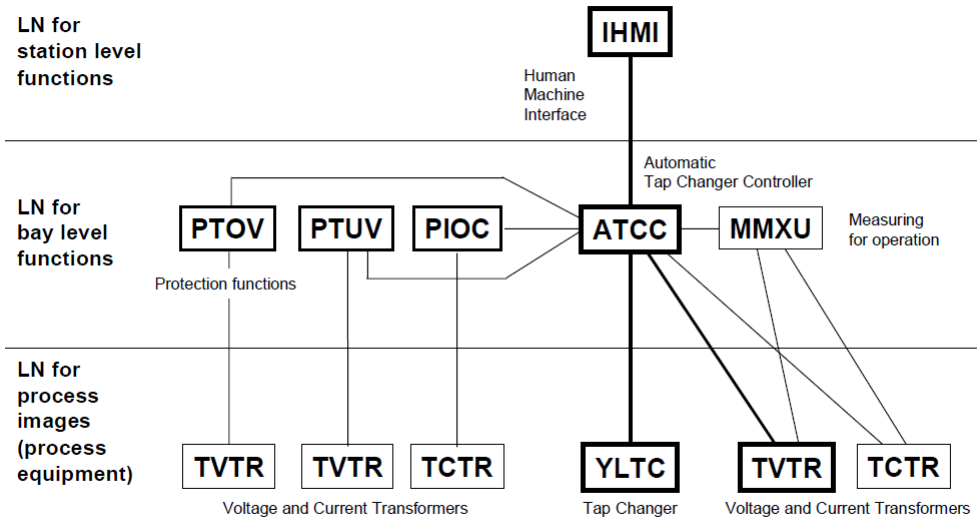
IEC 61850 Information Model

Logical Nodes – Example



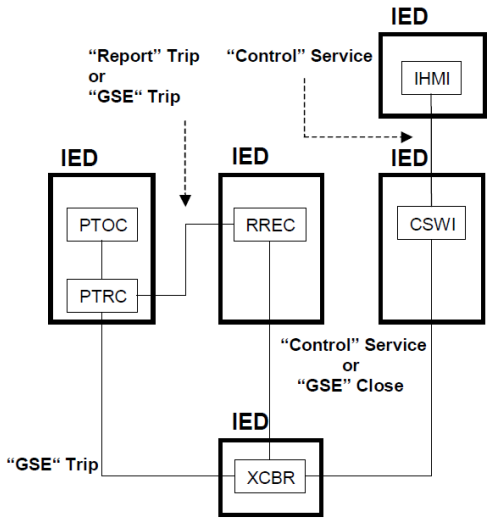
IEC 61850 Information Model

Logical Nodes – Example



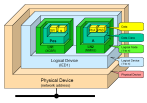
IEC 61850 Information Model

Logical Nodes – Example autoreclosure

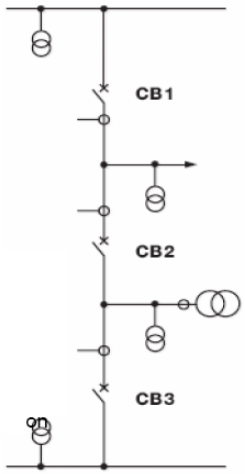


IEC 61850 example

How is this done?

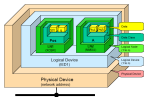


- Given the bay:



IEC 61850 example

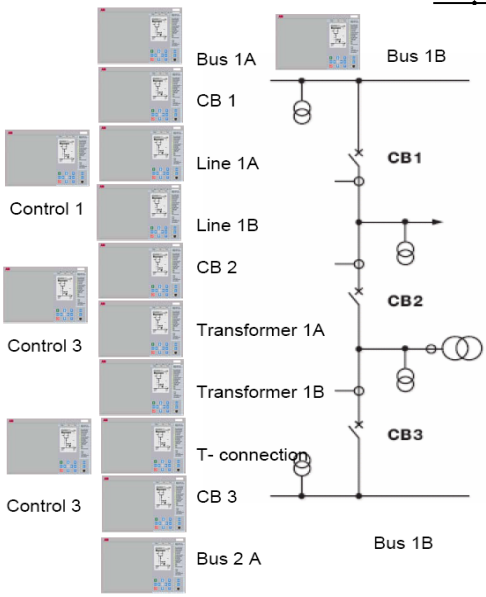
How is this achieved?



Possible LNs

PDIS 21	PDIF HZ	PDIF REF
PDIF 87B	PDIF 87L	PDIF 87T
PIOC 50	PIOC 50N	POCM 51/67
PEFM 51/67N	RBRF 50BF	PUVM 27
POVM 59	PTOF 81	PTUF 81
PVPH 24	PTTR 26	PSCH
RSYN 25	RREC 79	RBRF 50BF
CSWI	MMTR	MMXU

Add IEDs



IEC 61850 example

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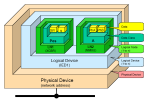
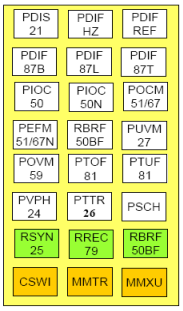
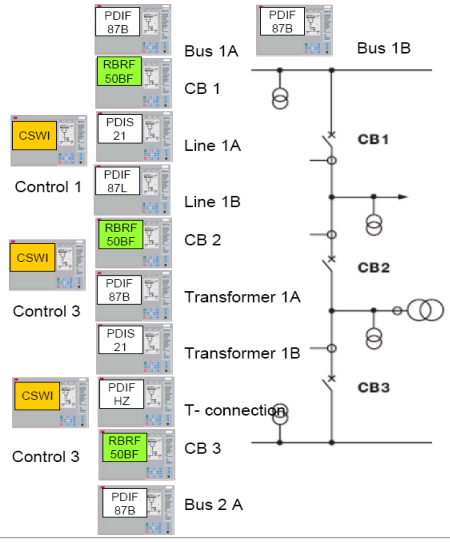


- Could allocate like this:





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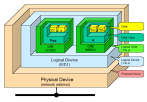
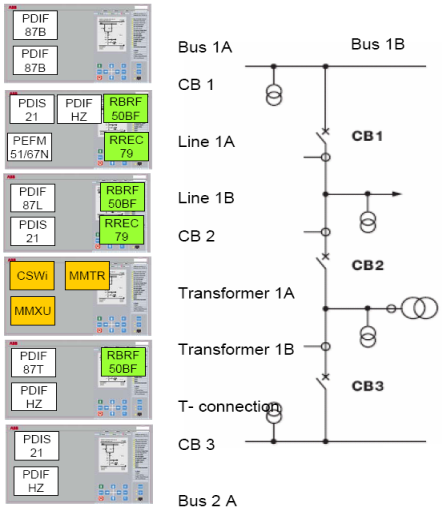
IEC 61850 example

How is this achieved?



- Or like this:



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- IEC 61850 Information Model
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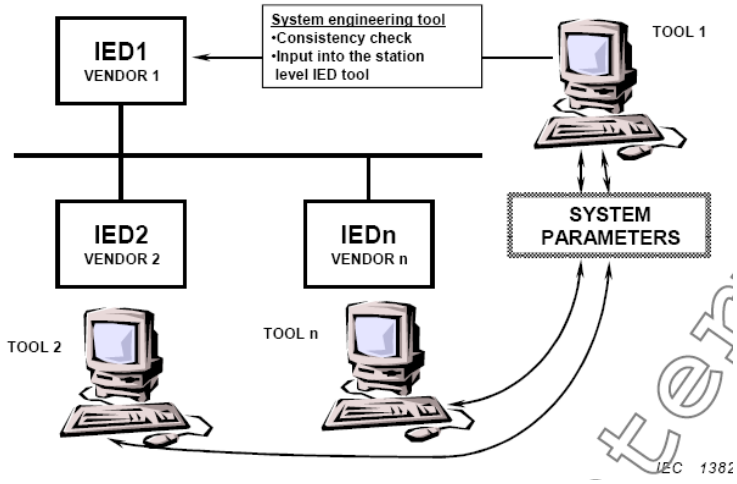
- Substation communication
  - Very brief introduction (more coming next week)

Specification and Configuration

- Integration and configuration process
- Substation Configuration Language (SCL)
- Design - System Specification Description (SSD)
- Specification – Substation Configuration Description (SCD)

Specification and Configuration

IEC 61850 configuration process



Specification and Configuration

Substation Configuration Language

- SCL is Part 6 of the 61850 standard
- Formal description of:
  - Substation automation system and
  - The switchyard
  - The relation between them
  - IED configuration

Specification and Configuration

Substation Configuration Language

- **SSD**: System Specification Description
  - Entire system
- **SCD**: Substation Configuration Description
  - Single substation
- **ICD**: IED Capability Description
  - Items supported by an IED
- **CID**: Configured IED Description
  - Specific IED

- XML files 

XML

eXtensible Markup Language

- Set of rules for encoding documents in a machine-readable form
- Hundreds of XML-based languages exist
- Human-readable data serialization
  - converting to a storable format

```
<?xml version="1.0"?>
<quiz>
 <question>
  Who was the forty-second
  president of the U.S.A.?
 </question>
 <answer>
  William Jefferson Clinton
 </answer>
 <!-- Note: We need to add
  more questions later.-->
</quiz>
```

XML

- Main concepts:
  - Character
  - Processor (parser) and Application
  - Markup and Content
  - Tag
  - Element
  - Attribute
  - XML declaration `<?xml version="1.0" encoding="UTF-8" ?>`

Databases and XML

eXtensible Markup Language

```
<?xml version="1.0" encoding="UTF-8" ?>
- <SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
    <Header id="SISCO_IED1_Complete" version="1" revision="2" toolID="xml spy" nameStructure="IEDName" />
  - <Communication>
    - <SubNetwork name="Subnetz1" type="8-MMS/TCP">
        <Text />
        <BitRate unit="b/s" multiplier="M">100</BitRate>
      - <ConnectedAP iedName="SISCO_IED1" apName="AXS4MMS_CIGRE">
        - <Address>
            <P type="IP" xsi:type="tP_IP">192.168.2.11</P>
            <P type="IP-SUBNET" xsi:type="tP_IP-SUBNET">255.255.255.0</P>
          </Address>
        - <GSE ldInst="CTRL" cbName="Control_DataSet1">
          - <Address>
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              <P type="VLAN-PRIORITY" xsi:type="tP_VLAN-PRIORITY">4</P>
              <P type="MAC-Address" xsi:type="tP_MAC-Address">01-0C-CD-01-F1-04</P>
              <P type="APPID" xsi:type="tP_APPID">0000</P>
            </Address>
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            <MaxTime unit="s" multiplier="m">2000</MaxTime>
          </GSE>
        </ConnectedAP>
      </SubNetwork>
    </Communication>
```

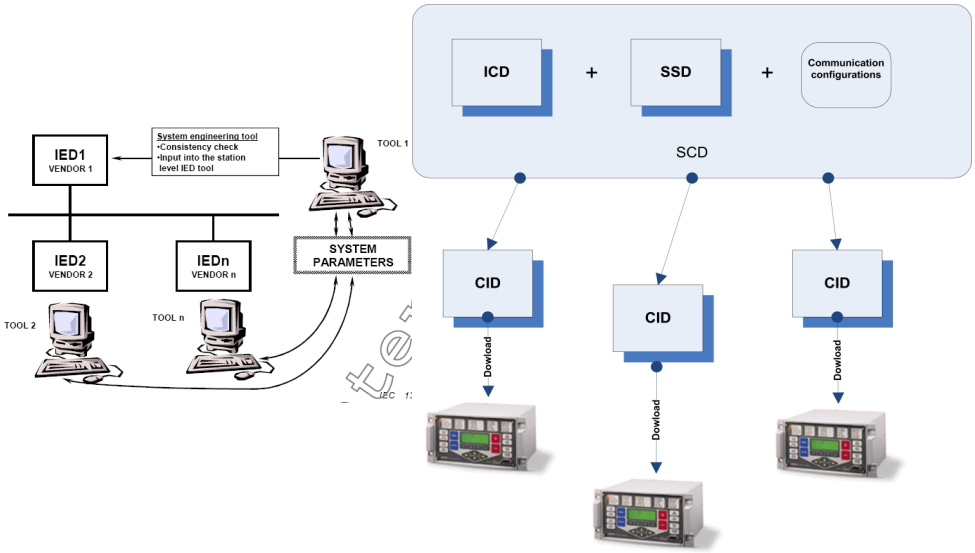
Specification and Configuration

Substation Configuration Language

```
<?xml version="1.0" encoding="UTF-8" ?>
- <SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
    <Header id="SISCO_IED1_Complete" version="1" revision="2" toolID="xml spy" nameStructure="IEDName" />
  - <Communication>
    - <SubNetwork name="Subnetz1" type="8-MMS/TCP">
        <Text />
        <BitRate unit="b/s" multiplier="M">100</BitRate>
      - <ConnectedAP iedName="SISCO_IED1" apName="AXS4MMS_CIGRE">
        - <Address>
            <P type="IP" xsi:type="tP_IP">192.168.2.11</P>
            <P type="IP-SUBNET" xsi:type="tP_IP-SUBNET">255.255.255.0</P>
          </Address>
        - <GSE ldInst="CTRL" cbName="Control_DataSet1">
          - <Address>
              <P type="VLAN-ID" xsi:type="tP_VLAN-ID">001</P>
              <P type="VLAN-PRIORITY" xsi:type="tP_VLAN-PRIORITY">4</P>
              <P type="MAC-Address" xsi:type="tP_MAC-Address">01-0C-CD-01-F1-04</P>
              <P type="APPID" xsi:type="tP_APPID">0000</P>
            </Address>
            <MinTime unit="s" multiplier="m">10</MinTime>
            <MaxTime unit="s" multiplier="m">2000</MaxTime>
          </GSE>
        </ConnectedAP>
      </SubNetwork>
    </Communication>
```

Specification and Configuration

IEC 61850 configuration process

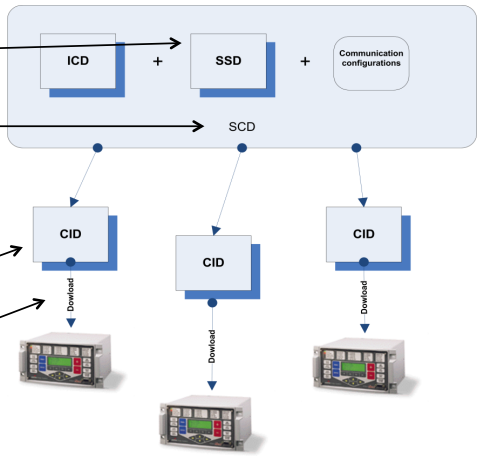


Specification and Configuration

IEC 61850 configuration process

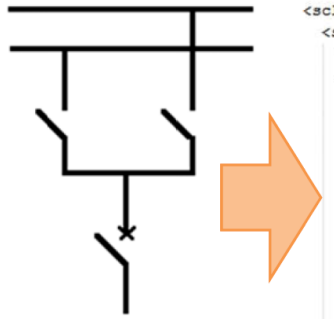
Design Sequence:

1. Design SSD
2. Create SCD = integrate SSD with manufacturer provided ICDs and add communication configuration
3. Generate IED specific CID for each IED
4. Download CIDs into IEDs



Specification and Configuration

Design - System Specification Description (SSD)

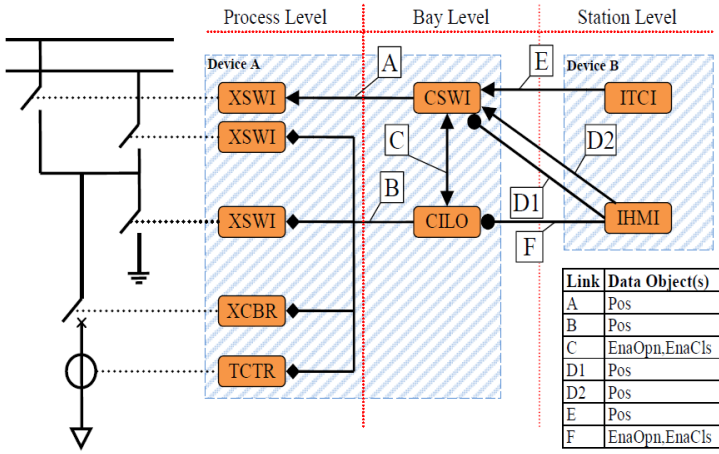


```
<scl:Substation desc="25/10 kV substation" name="ABC">
  <scl:VoltageLevel desc="25kV sectie" name="K1">
    <scl:Voltage multiplier="k" unit="V">25</scl:Voltage>
    <scl:Bay desc="25kVLinefeeder" name="Q8">
      <scl:ConductingEquipment desc="Disconnector" name="QB1" type="DIS">
        <scl:Terminal bayName="Q8" cNodeName="CN1" connectivityNode="#CN1"
        <scl:Terminal bayName="Q8" cNodeName="CN2" connectivityNode="#CN2"
      </scl:ConductingEquipment>
      <scl:ConductingEquipment desc="Disconnector" name="QB2" type="DIS">
        <scl:Terminal bayName="Q8" cNodeName="CN3" connectivityNode="#CN3"
        <scl:Terminal bayName="Q8" cNodeName="CN2" connectivityNode="#CN2"
      </scl:ConductingEquipment>
      <scl:ConductingEquipment desc="Breaker" name="QA1" type="CBR">
        <scl:Terminal bayName="Q8" cNodeName="CN2" connectivityNode="#CN2"
        <scl:Terminal bayName="Q8" cNodeName="CN5" connectivityNode="#CN5"
      </scl:ConductingEquipment>
```

- Single-line diagram represented as SSD file

Specification and Configuration

Specification – Substation Configuration Description (SCD)



Legend				
Link	**Data Object(s)**	**Data Attribute(s)**	**Msg. type**	**PC**
A	Pos	[control structure]	7	P2(TT2)
B	Pos	stVal/q/t	1B	P2(TT4)
C	EnaOpn.EnaCls	stVal/q/t, stVal/q/t	2	P1(TT3)
D1	Pos	stVal/q/t	2	P1(TT3)
D2	Pos	[control structure]	7	P2(TT2)
E	Pos	[control structure]	7	P2(TT2)
F	EnaOpn.EnaCls	stVal/q/t, stVal/q/t	2	P1(TT3)

Specification and Configuration

IEC 61850 configuration process

Design Sequence:

1. Design SSD
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3. Generate IED specific CID for each IED
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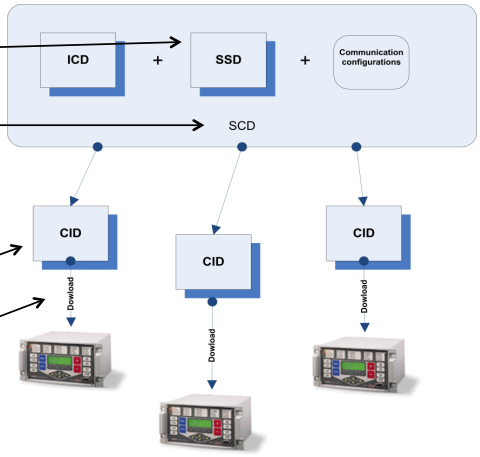
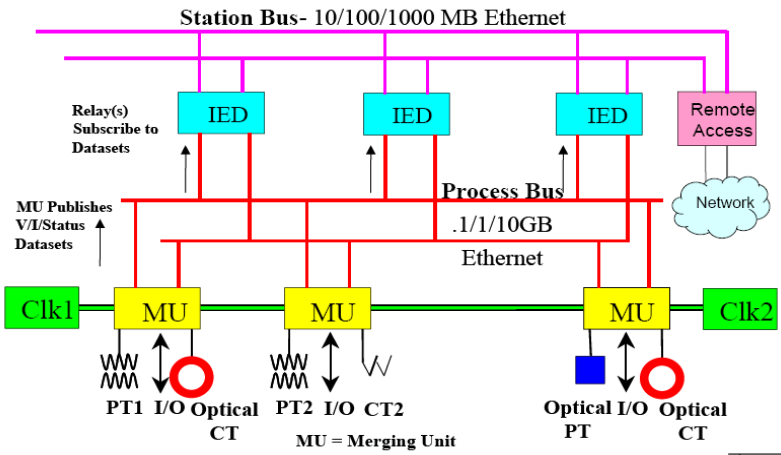
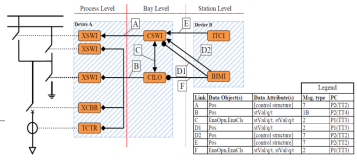


Specification and Configuration

IEC 61850 substation



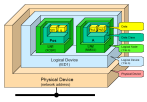


Outline of the lecture

- Recap of modern substation architectures
  - IEC 61850 substation
  - Purpose and scope of IEC 61850
- IEC 61850 Information Model
- Specification and configuration
- Substation communication
  - Very brief introduction (more coming next week)

Substation communication

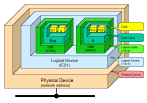
Overview

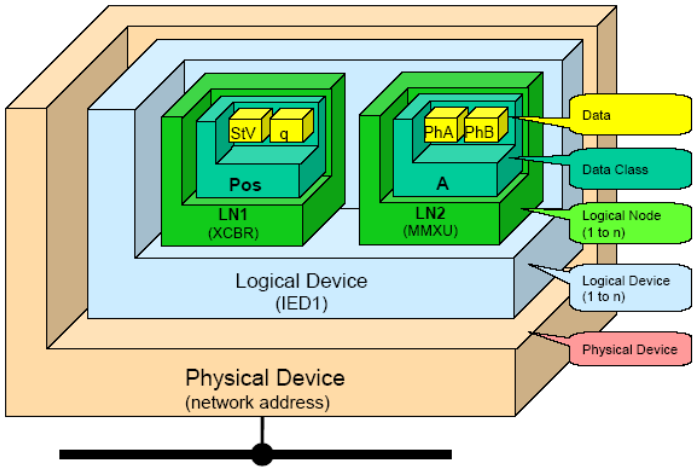


- OO information exchange
- Protocols

Substation communication

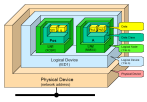
OO information exchange

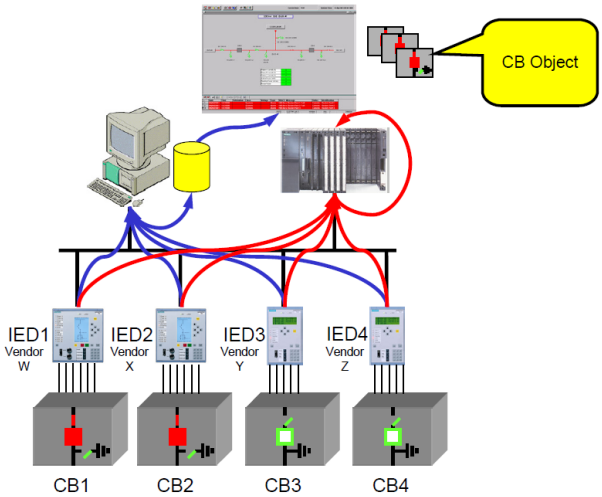


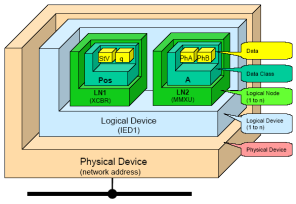


Substation communication

OO information exchange - Vertical

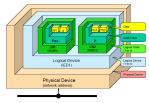


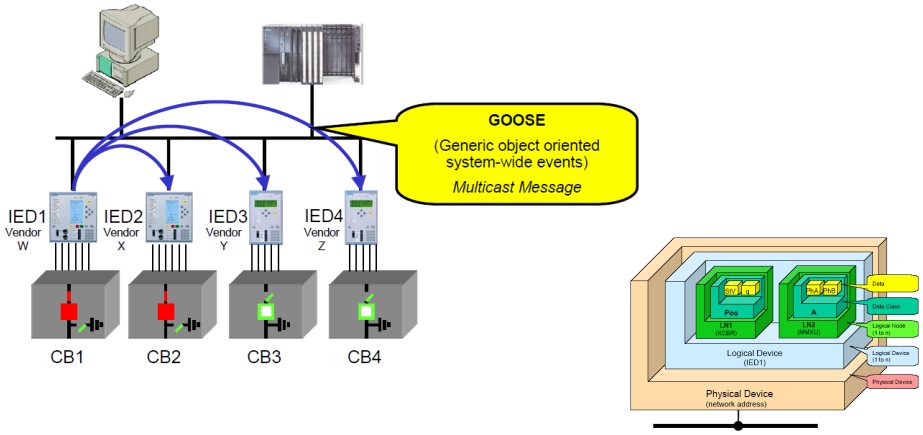




Substation communication

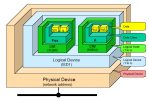
OO information exchange - Horizontal

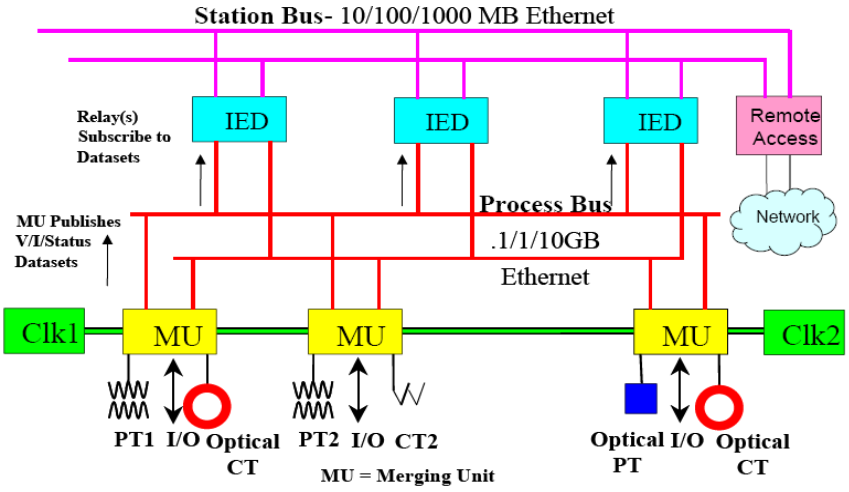




Substation communication

Protocols





The End