IEEE - Nashville, TN Technical Meeting - April 30, 2015

“Communications”

Rick Preston, Siemens Energy Automation

Overview of Topics

- Communications (Protocols, Media, etc.)
- What is IEC61850?
- GOOSE Messaging
- Simplified Network Topology
- Redundancy Options for Communications Networks (eRSTP, PRP, HSR)

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Communications Protocols

DNP3

Modbus®

PROFIBUS®

Meet the standard IEC 61850

OPC™

PROFINET®

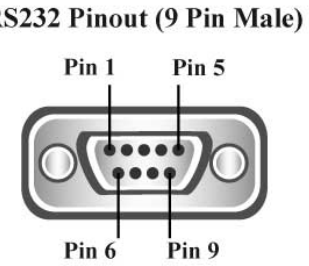
DeviceNet™

Communication Types – Serial

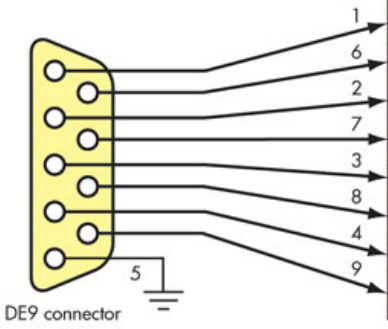
Serial Communications using Electrical Conductors (Twisted Pair)

RS232

Pin 1	DCD
Pin 2	RXD
Pin 3	TXD
Pin 4	DTR
Pin 5	GND
Pin 6	DSR
Pin 7	RTS
Pin 8	CTS
Pin 9	RI



RS485

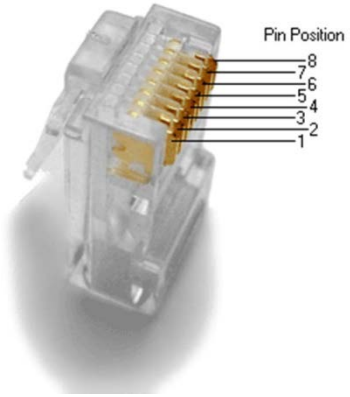


Code	Description
DCD	Data carrier detect
DSR	Data set ready
RD	Receive data line
RST	Request to send
TD	Transmit data line
CTS	Clear to send
DTR	Data terminal ready
RI	Ring indicator

Serial Communications using Fiber Optic Cabling

Communication Types – Ethernet TCP/IP

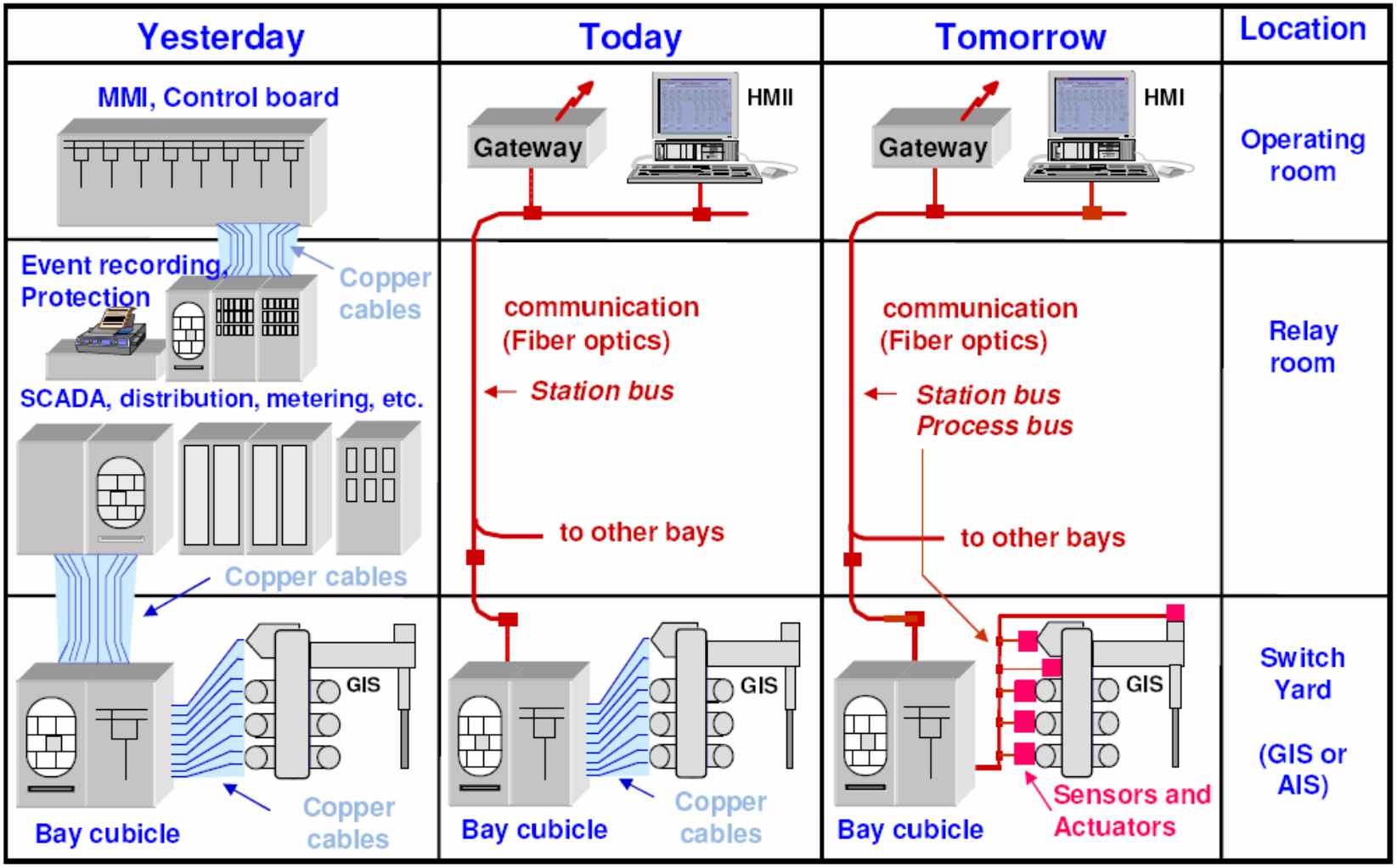
Ethernet Communications using Electrical Conductors (RJ45)



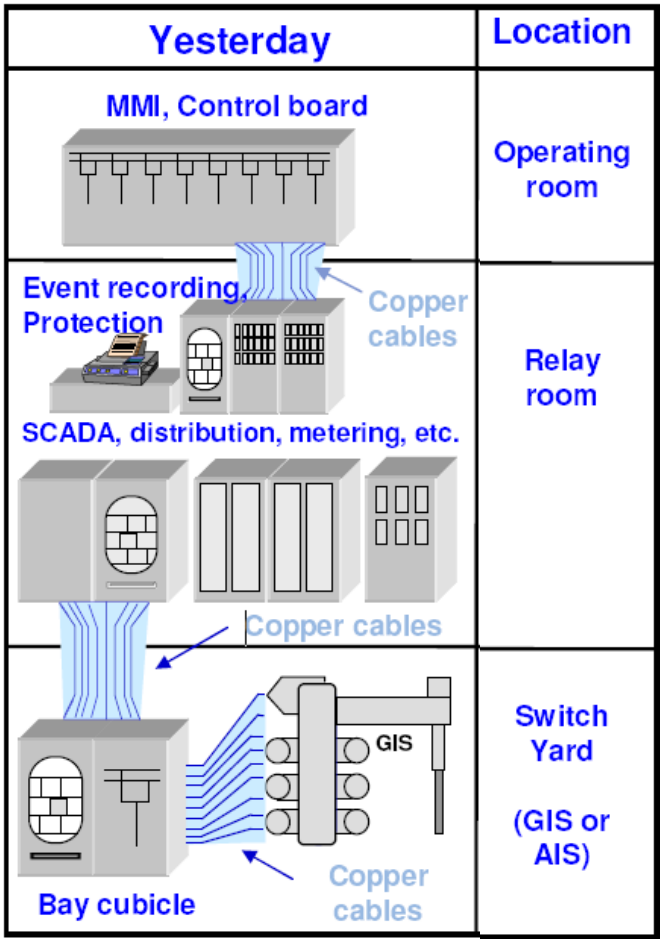
Ethernet Communications using Fiber Optic Cabling

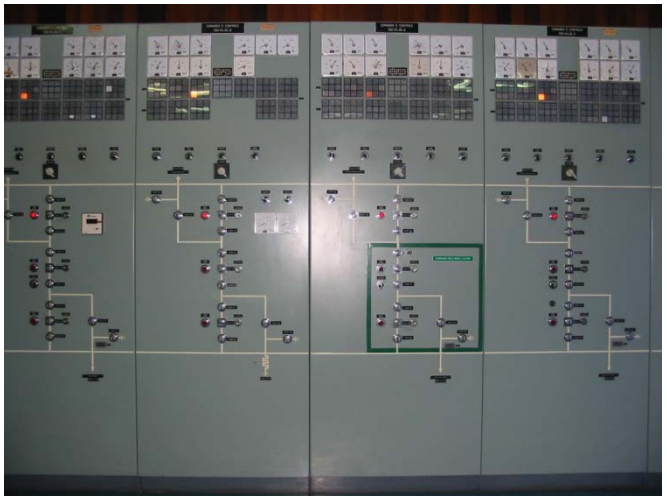
Based on Ethernet standard

Substation Automation Evolution

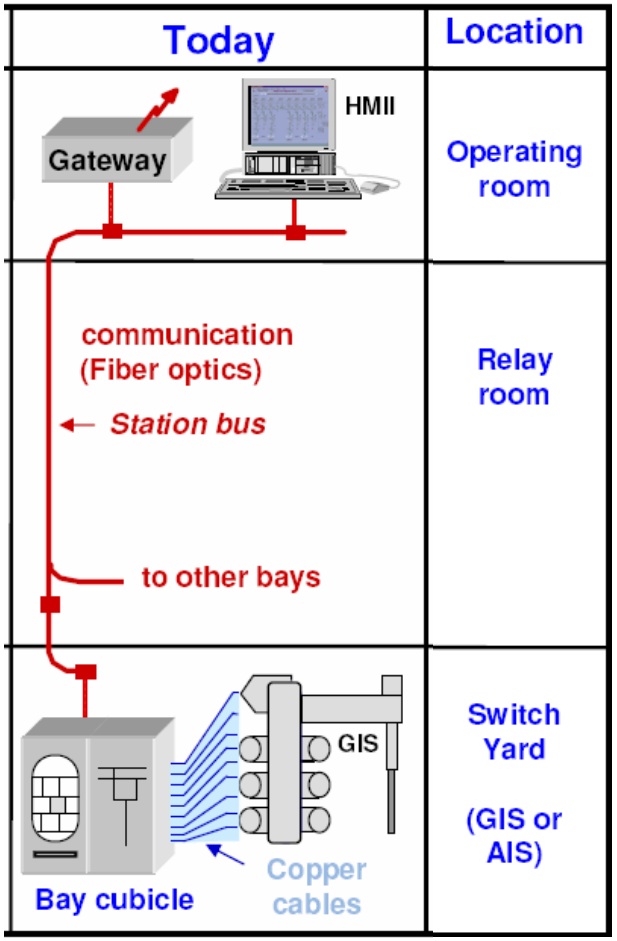


Yesterday

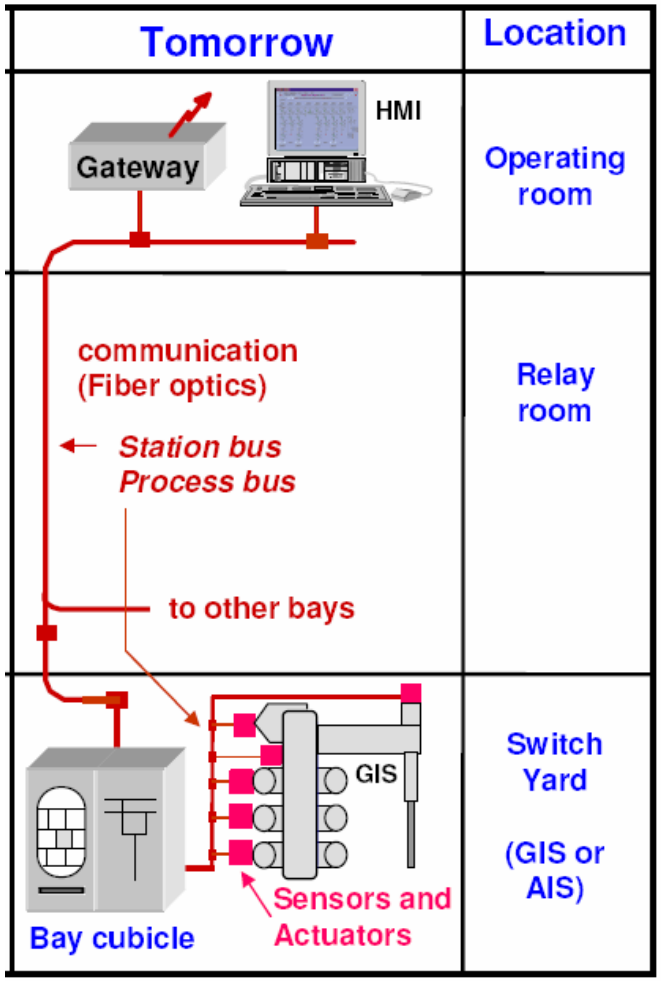




Nowadays



TOMORROW



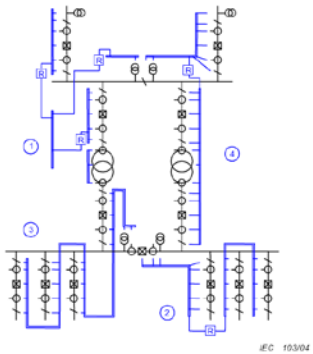


Figure B.1 – Alternative process bus architectures

Example Substation – Mixing Serial and Ethernet Protocols

Corporate Network TCP/IP

HMI

HMI

OPC

DNP

Full Server

SICAM STATION UNIT

Station Bus IEC 61850 (Ethernet)

Protection, Control, Metering
Peer to Peer or Goose Capable

Modbus, DNP,
Profibus DP
Protection, Control,
Metering

Profinet, DNP
Protection,
Control,
Metering

PLC

Goose Messaging
Relay Setting
Fault records
Time Synchronization
Scada
Network Management (SNMP)

Data highway: 100 MBit/s Ethernet

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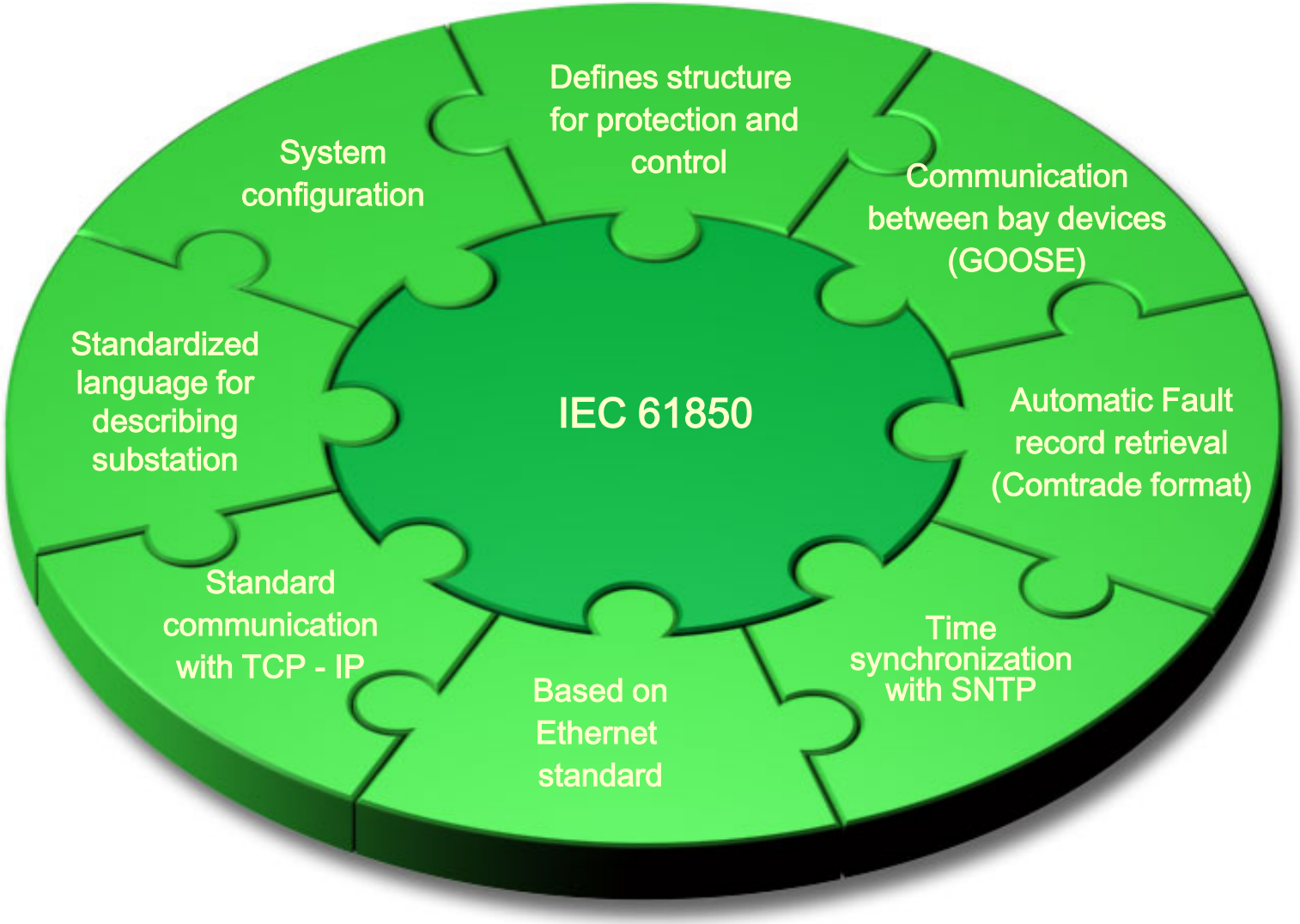
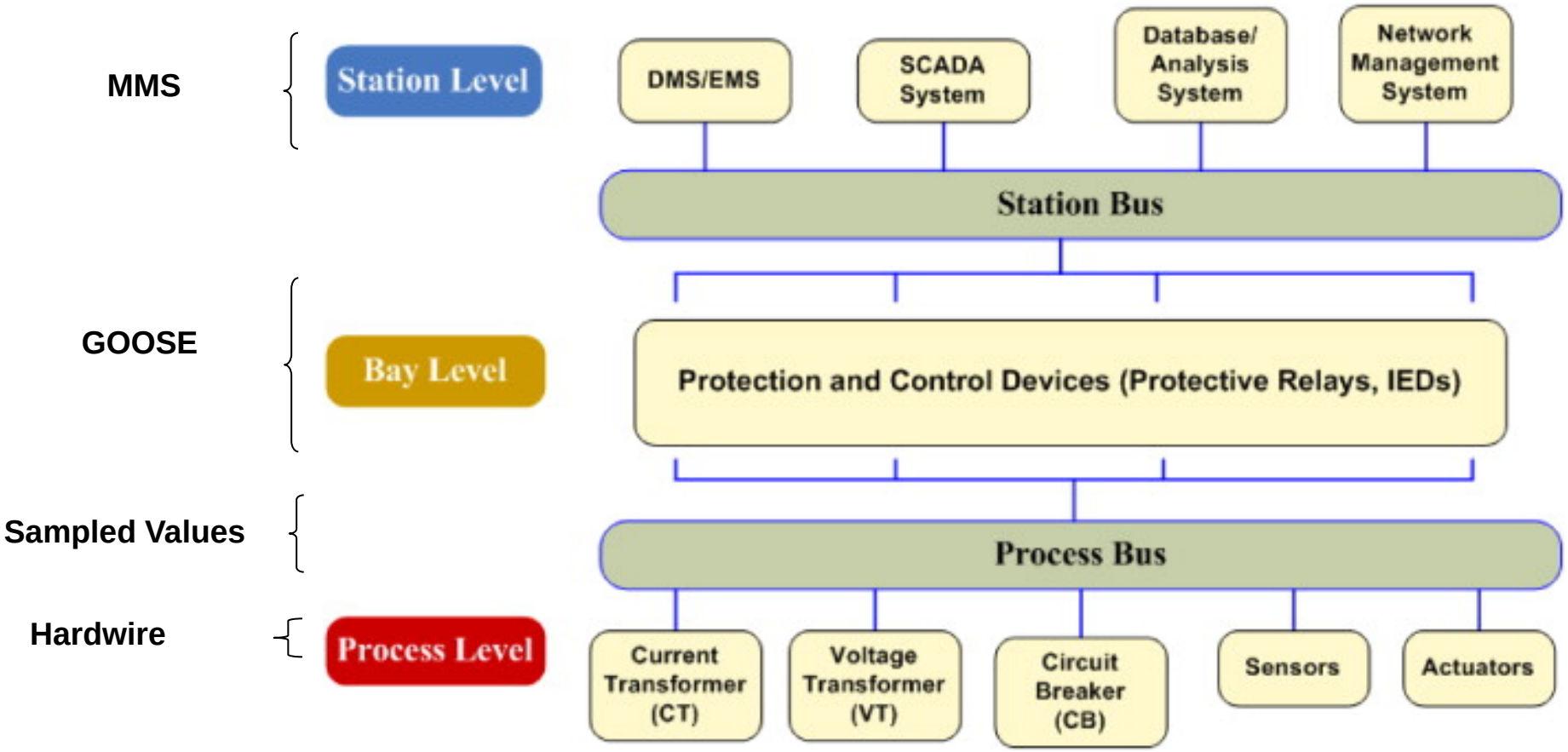
What Is IEC 61850?

IEC 61850 is a standard for the design of electrical substation automation

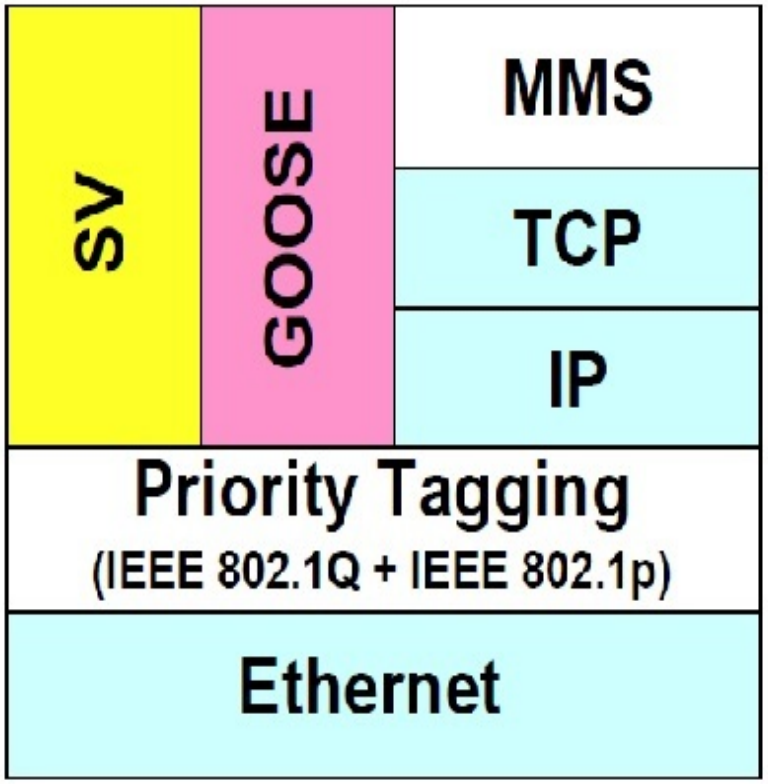


Typical Substation Architecture



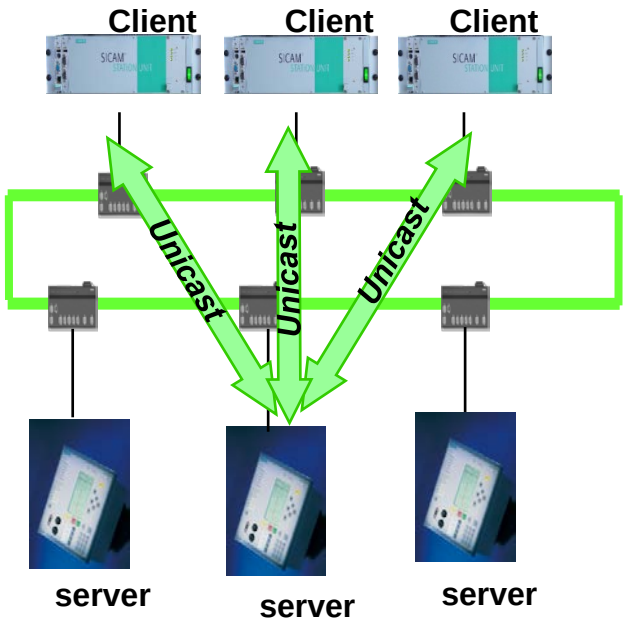
IEC61850 Protocols

- **Three IEC61850 Protocols**
  - **MMS (Manufacturing Message Specification)**
  - **GOOSE (Generic Object oriented Substation Event)**
  - **SV (Sampled Values)**



IEC-61850 Communication Stack

Network Concept –IEC 61850



Unicast

(client-server)

(MMS)

vs

Multicast

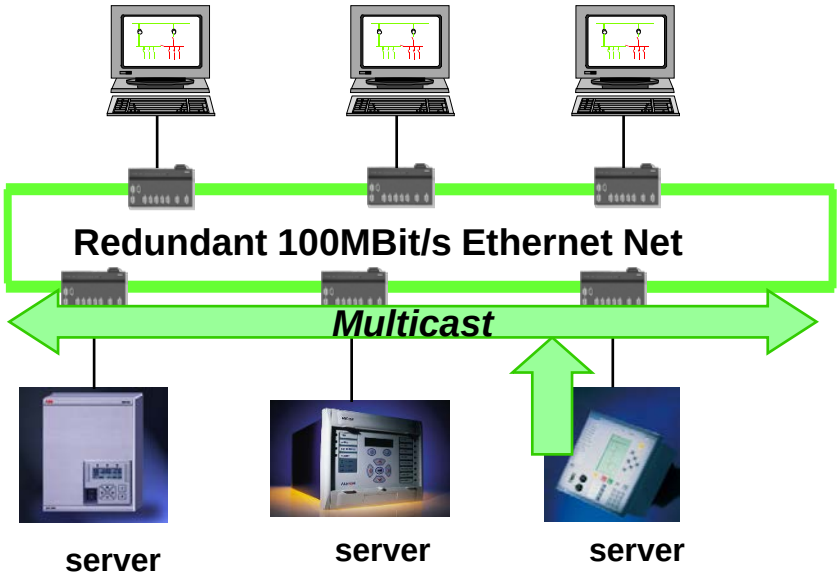
(peer to peer)

&

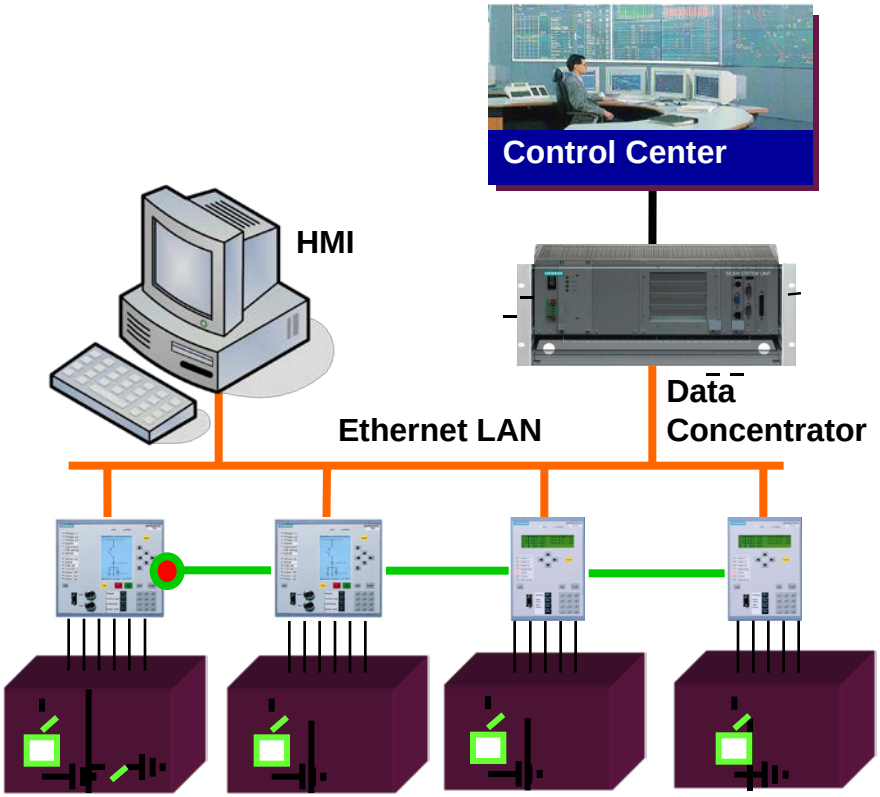
(one to many)

(GOOSE)

(Sampled Values)



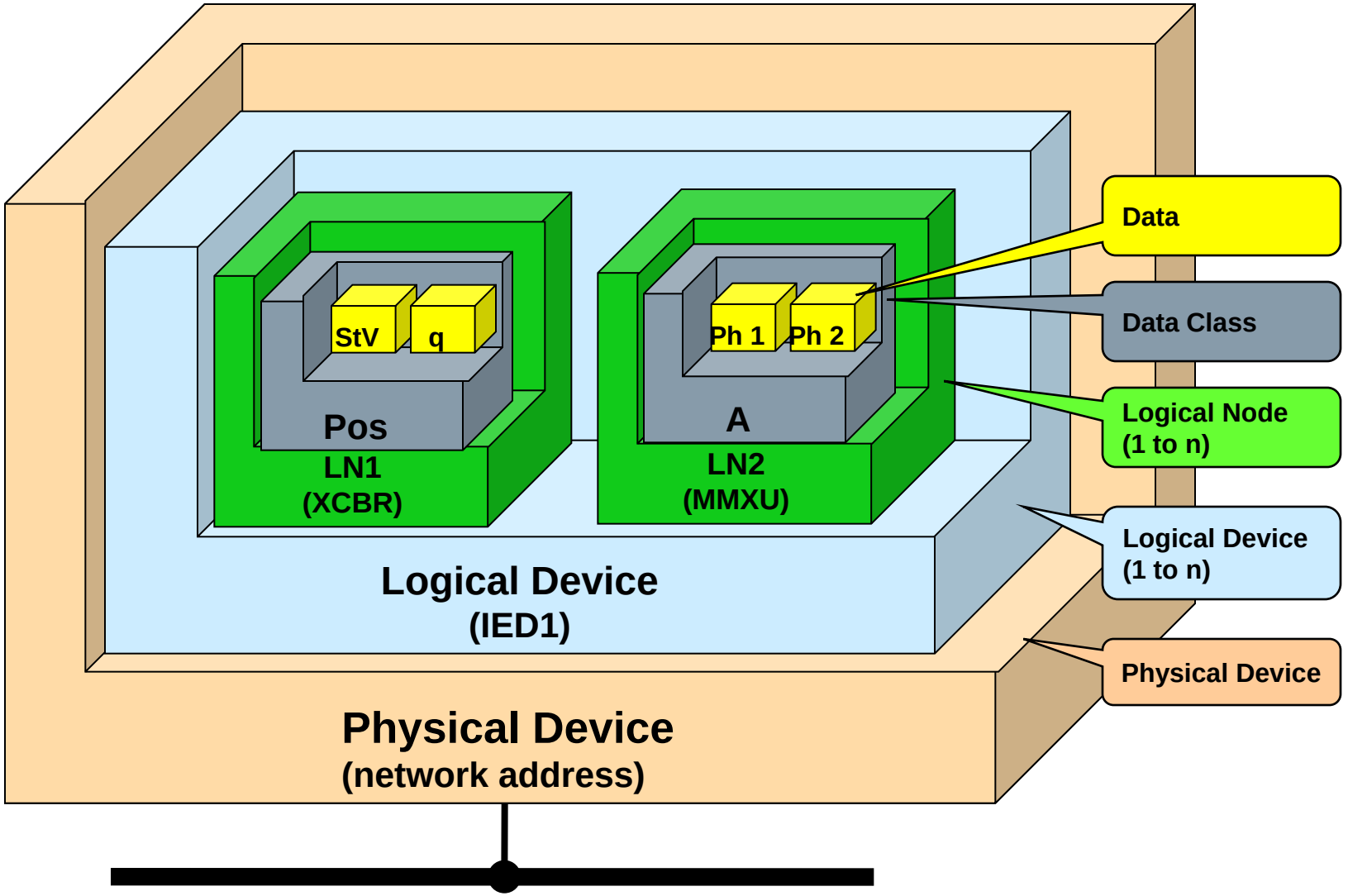
The IEC 61850 Standard in Brief



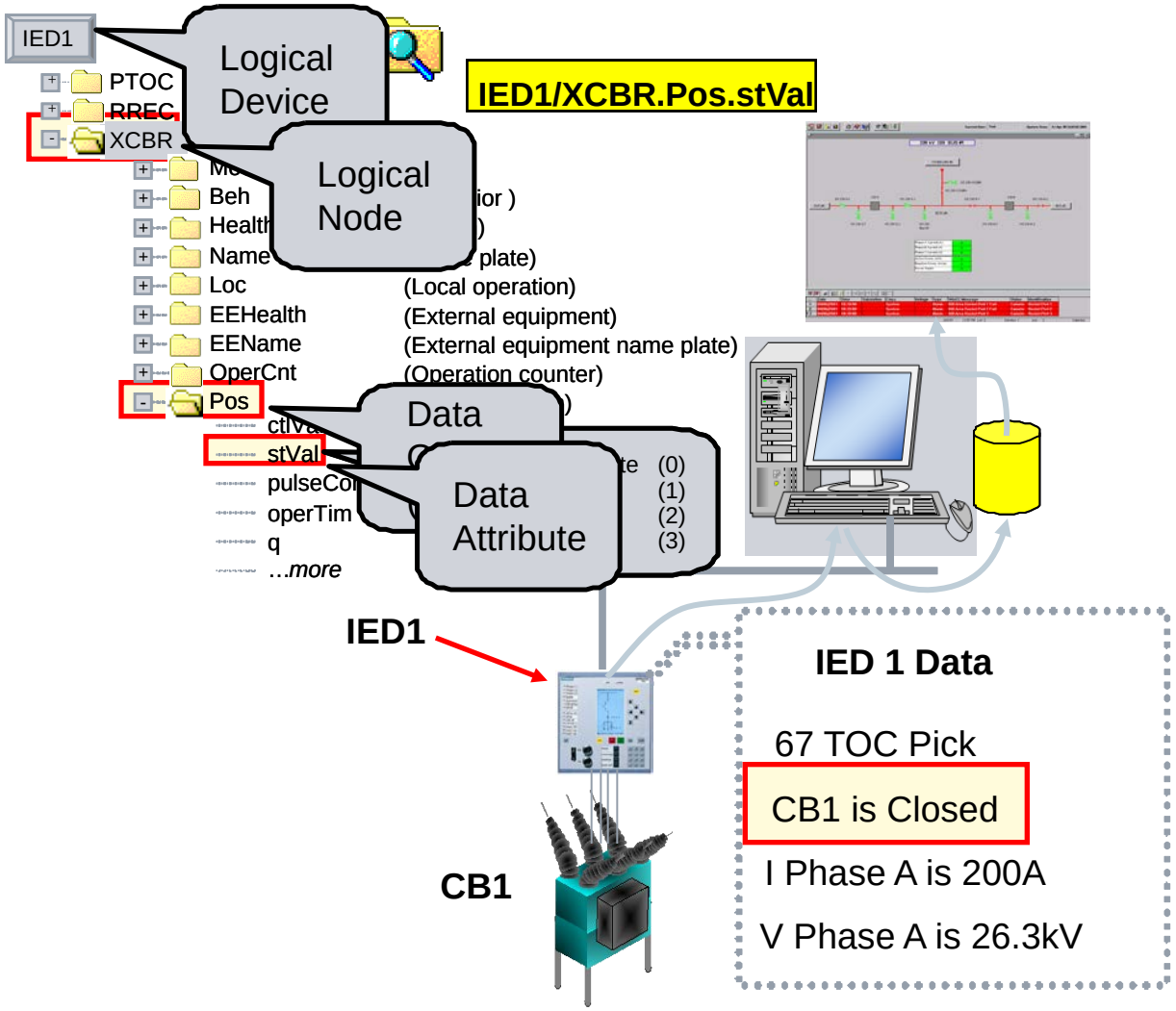
Meet the standard
IEC 61850

- **IEC 61850** provides a **framework** to describe all automation and protection functions of a substation or electrical system:
- **Standardized language** categorized with extensive naming convention based off the electrical system
- **Standardized Engineering** based on vendor-independent function descriptions
  - Use devices from different vendors
  - Re-use engineering in the future
- **Ethernet-based** communications
- **Interoperability** between different vendors
- **Non-hardwired** inter-device communication providing protection coordination

IEC61850 Data Structure



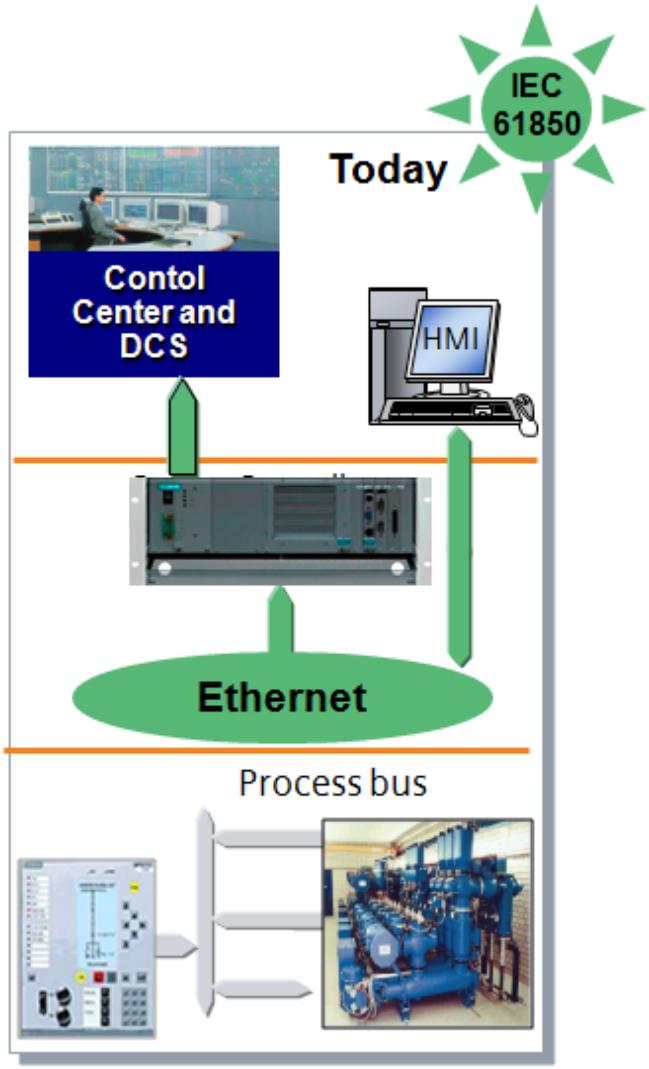
IEC61850 Data Structure



IEC 61850 defines a data model to enable standardization

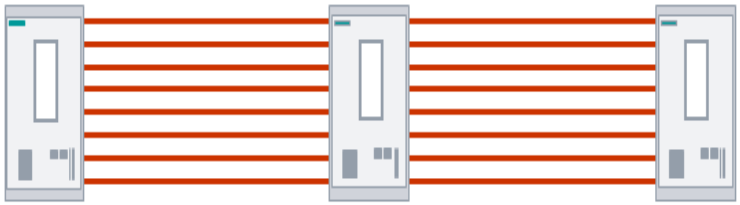
Benefits of IEC61850

1. Communications architecture for modeling entire power system.
2. Defined data structure that eliminates the need for time consuming mapping.
3. Promotion of high inter-operability between systems from different manufacturers devices.
4. A common language for describing a power system data model.
5. Definition of the complete testing for devices which conforms to the standard.

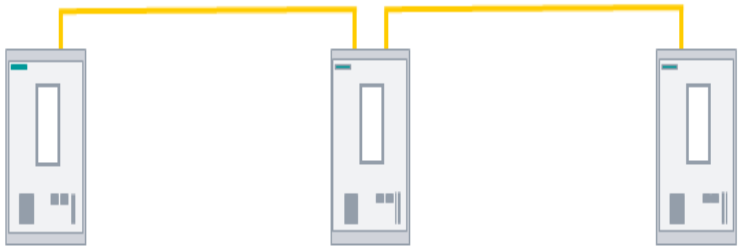


Benefits of IEC61850

Conventional Wiring



Wiring with IEC 61850



The implementation of IEC 61850 allows for a significant cost reduction in engineering and material costs during substation design, testing, construction and commissioning

IEC 61850 enables up to 70% reduction in wires

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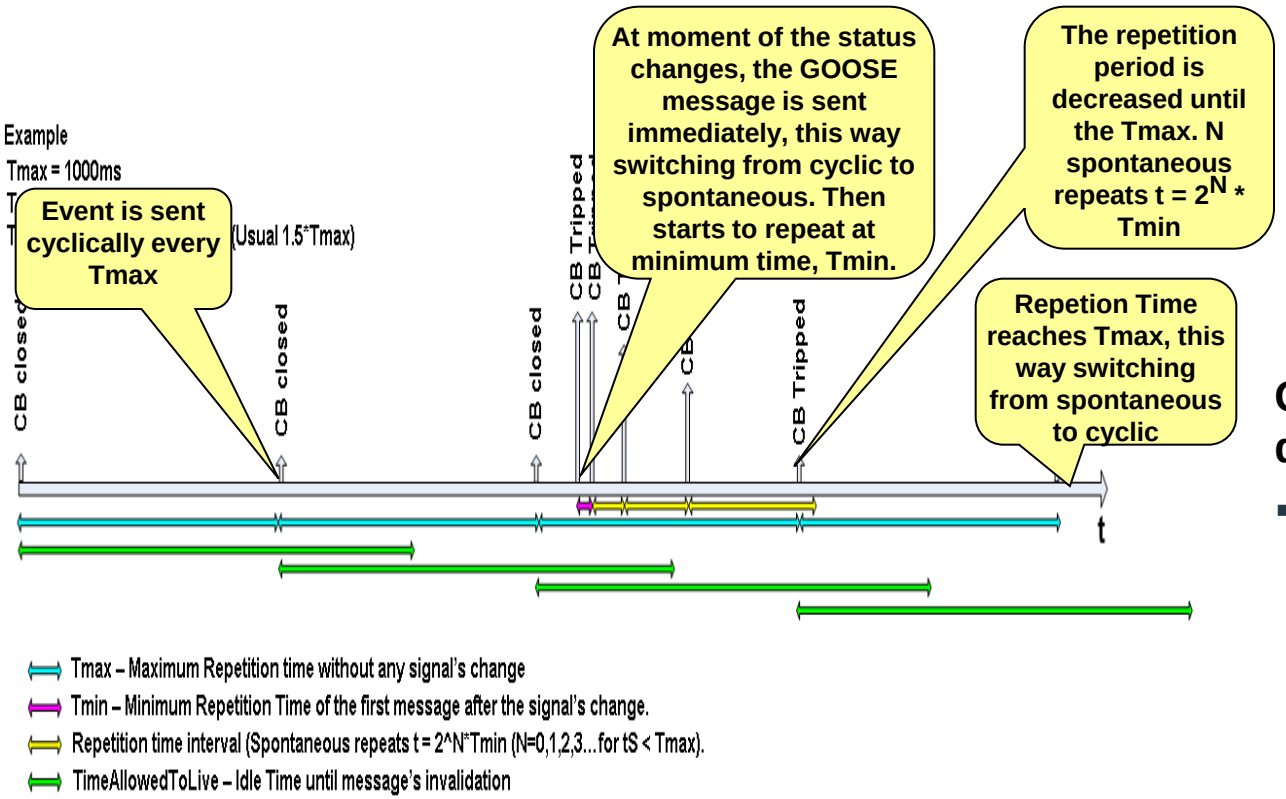
IEC61850 – GOOSE MECHANISM



GOOSE message validity and delivery

- GOOSE Repetition
  - $Time_{Min}=T_{Min}$
  - $Time_{Max=}T_{max}$
- Trigger event
- Rapid fire mode
- GOOSE Status number
- GOOSE Sequence number

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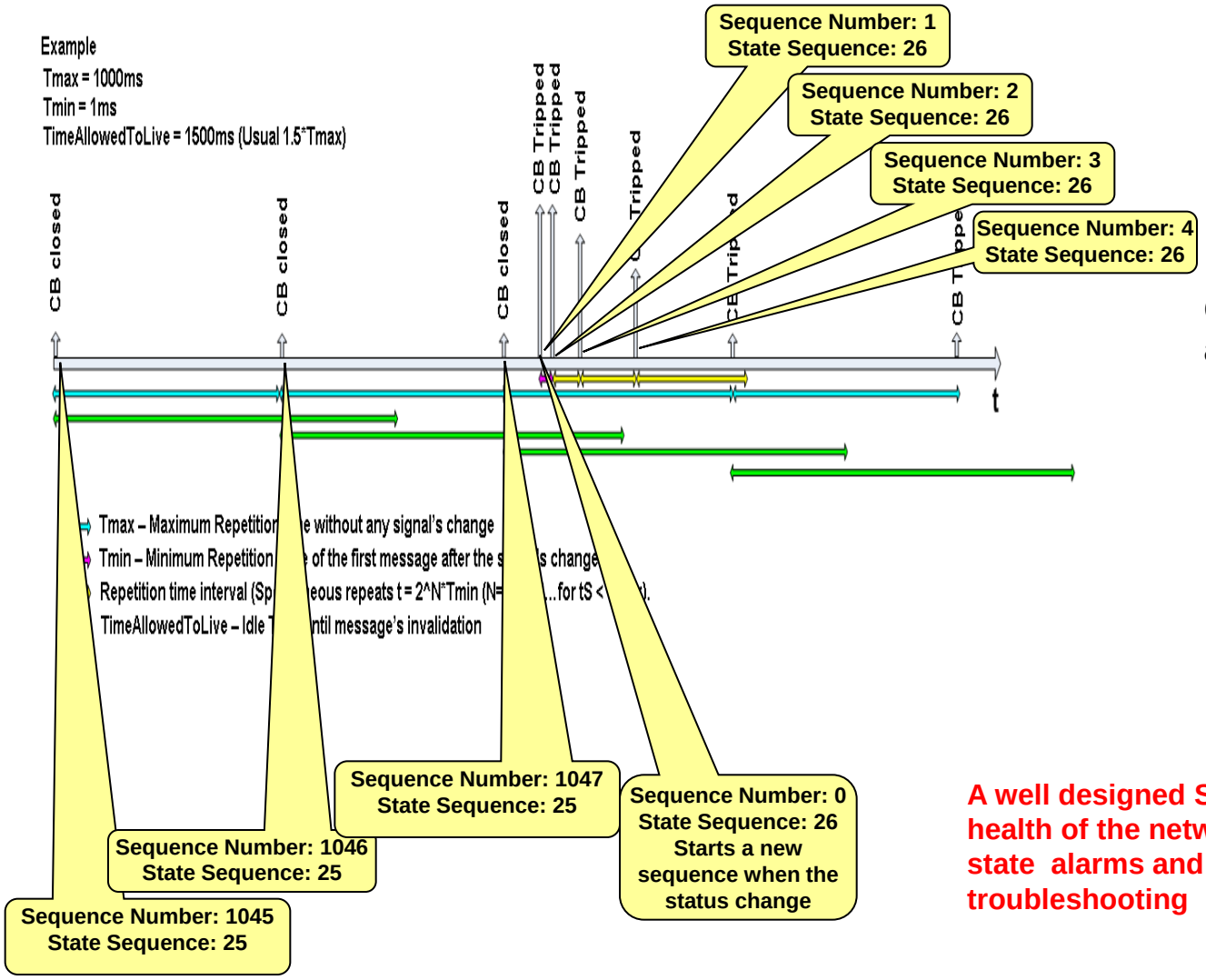

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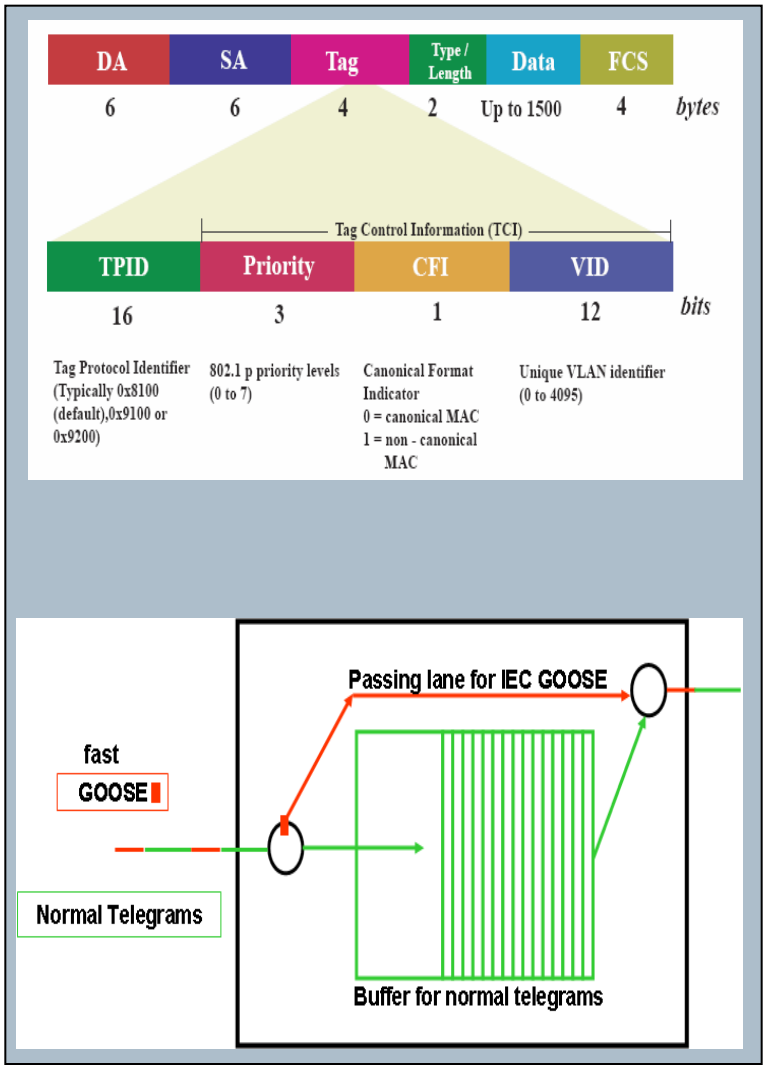
- GOOSE Sequence number

A well designed Substation HMI can determine the health of the network by monitoring sequence or state alarms and indications for fast network troubleshooting

IEC 61850 Concepts- GOOSE Using the 802.1Q Frame – Layer 2

CONCEPTS OF THE IEC 61850 STANDARD

- GOOSE Telegram structure
  - 4 Tag bytes define the tag control information
  - Up to 1500 data bytes are available per message
- GOOSE messages must be prioritized
  - 0-7 (lowest priority)



IEC 61850 – GOOSE MECHANISM

-**Fast:**

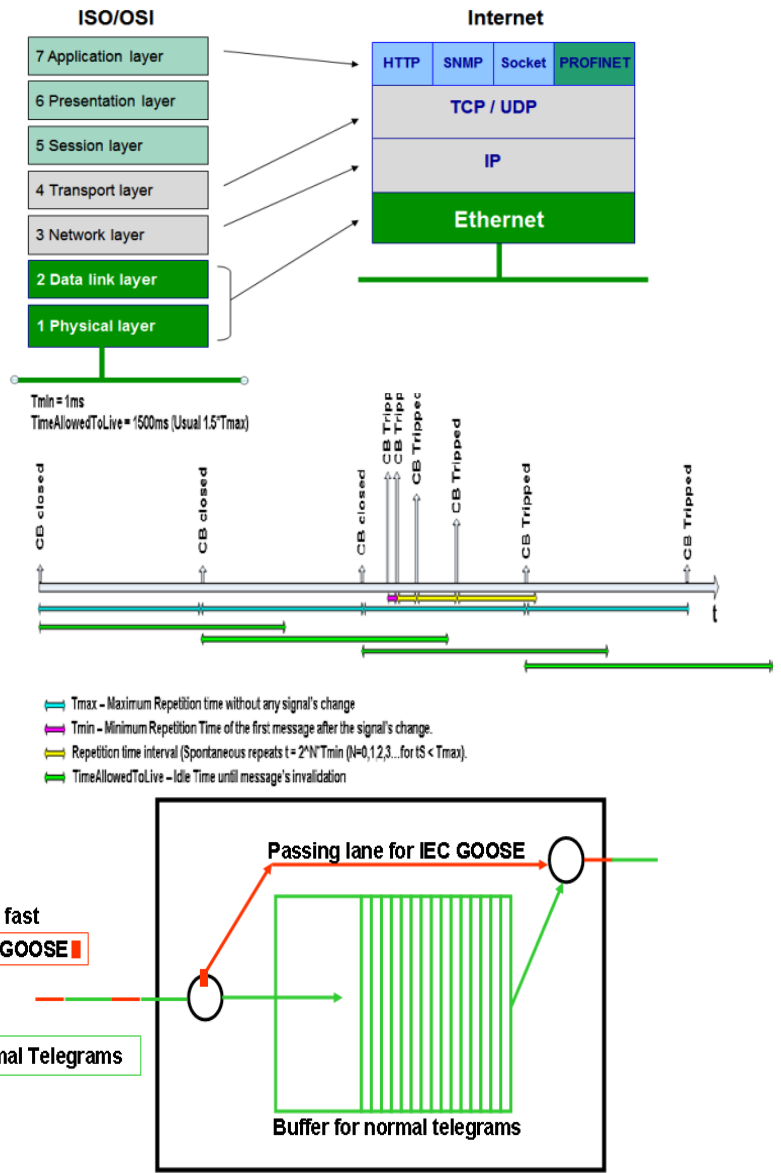
Using layer 2 frames, doesn't require any other layer's confirmation or connection. It is a multicast message without connection or confirmation.

-**Ensure delivery of message:**

Mathematically, by repeating the same message in a short period of time, it will ensure delivery of the message. Besides, the Receptor verify the message quality and check if the Transmitter is there by usage of TimeAllowToLive.

-**Priority:**

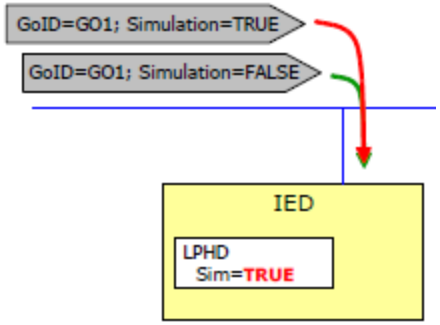
By usage of the priority tag (802.1p).



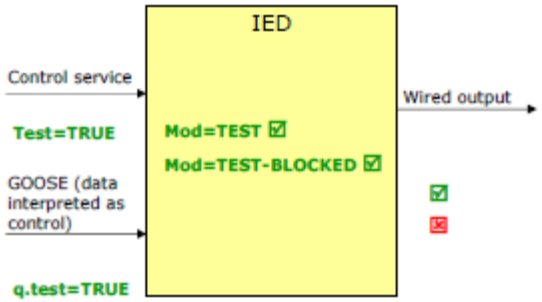
Enhancements with Edition 2 of IEC61850

Faster Testing and Commissioning Tools for lower Maintenance Cost

A



Simulation of a GOOSE Message



Command with Test =TRUE

IEC 61850 standard continues to evolve with the publication of edition 2 which simplifies the process of testing and commissioning via a Test and Simulation Modes

Ethernet Enables Interoperability and Save Costs

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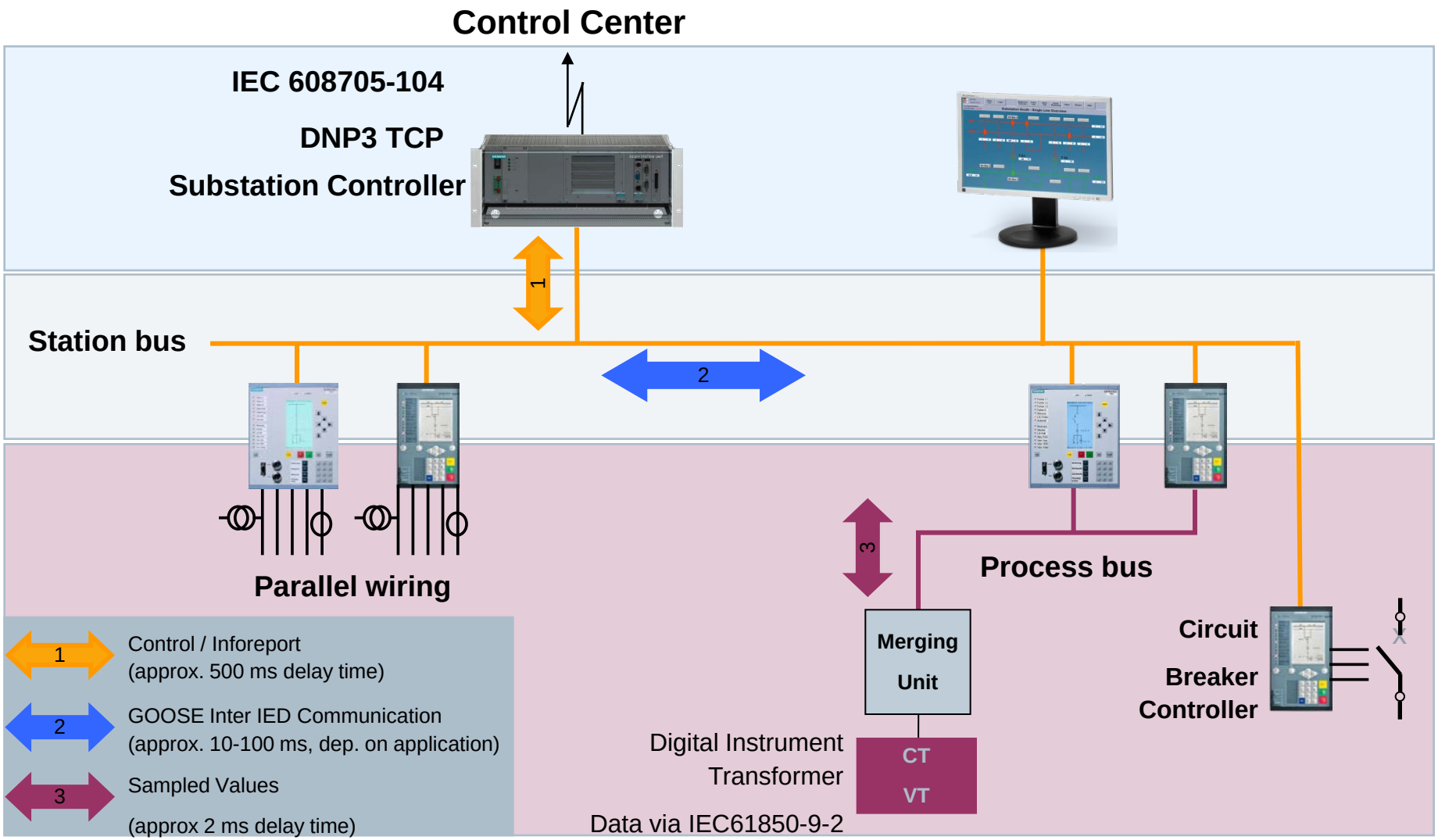
IEC 61850 communication within a substation



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Principals of redundancy mechanisms

Redundancy with recovery time

- Dual Homing Link Redundancy
  Two active links, one is sending,
  sending link changes if one link is down

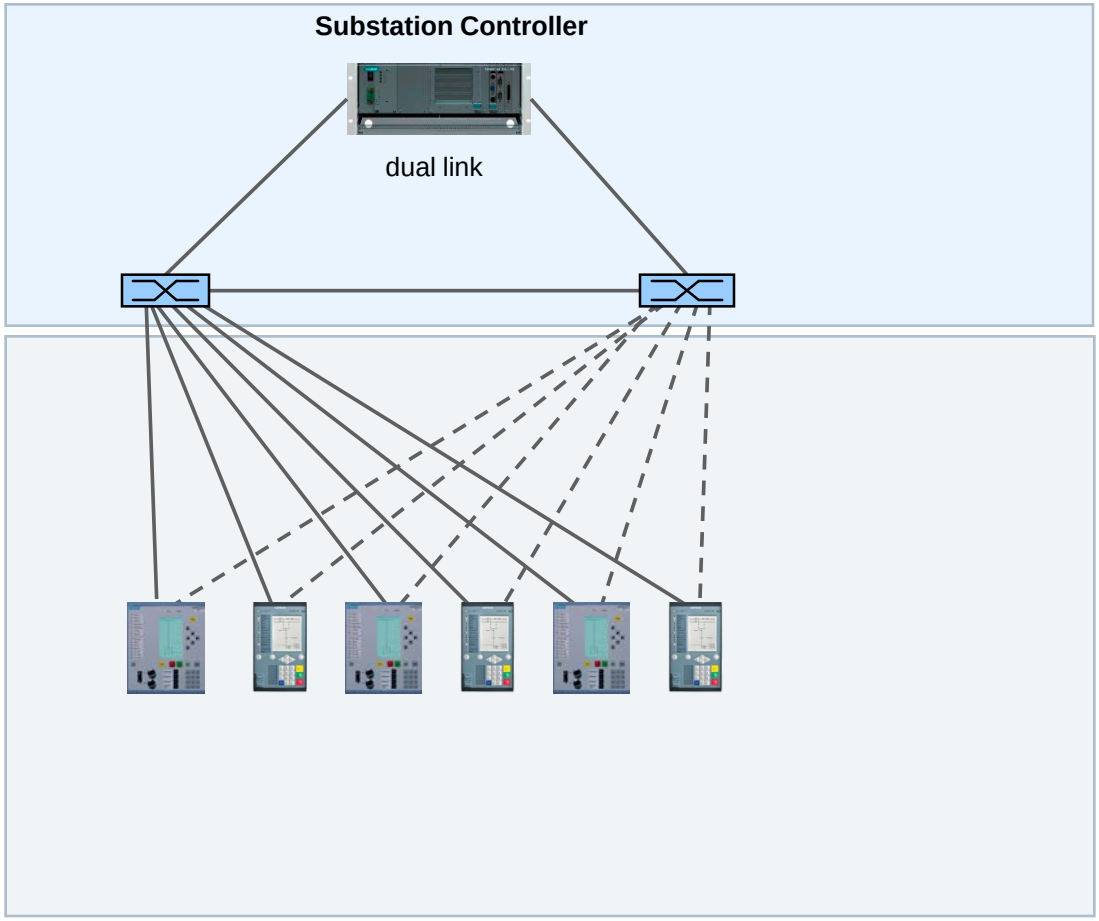
- RSTP Rapid Spanning Tree Protocol
  Redundancy IEEE 802.1D-2004

Seamless Redundancy Systems:

- Parallel Redundancy Protocol IEC 62439-3.4
  Two active links, both sending, parallel configuration

- High availability seamless redundancy IEC 62439-3.5
  Two active links, both sending, ring configuration

Principal of Dual Link (Dual homing) Redundancy



- 2 external Switches – directly connected
- Devices connected in star structure to switches
- Devices with two Ethernet ports
- Port 1 is sending
- Port 2 is standby

→ Established since 2004.

Features of Dual Link Redundancy

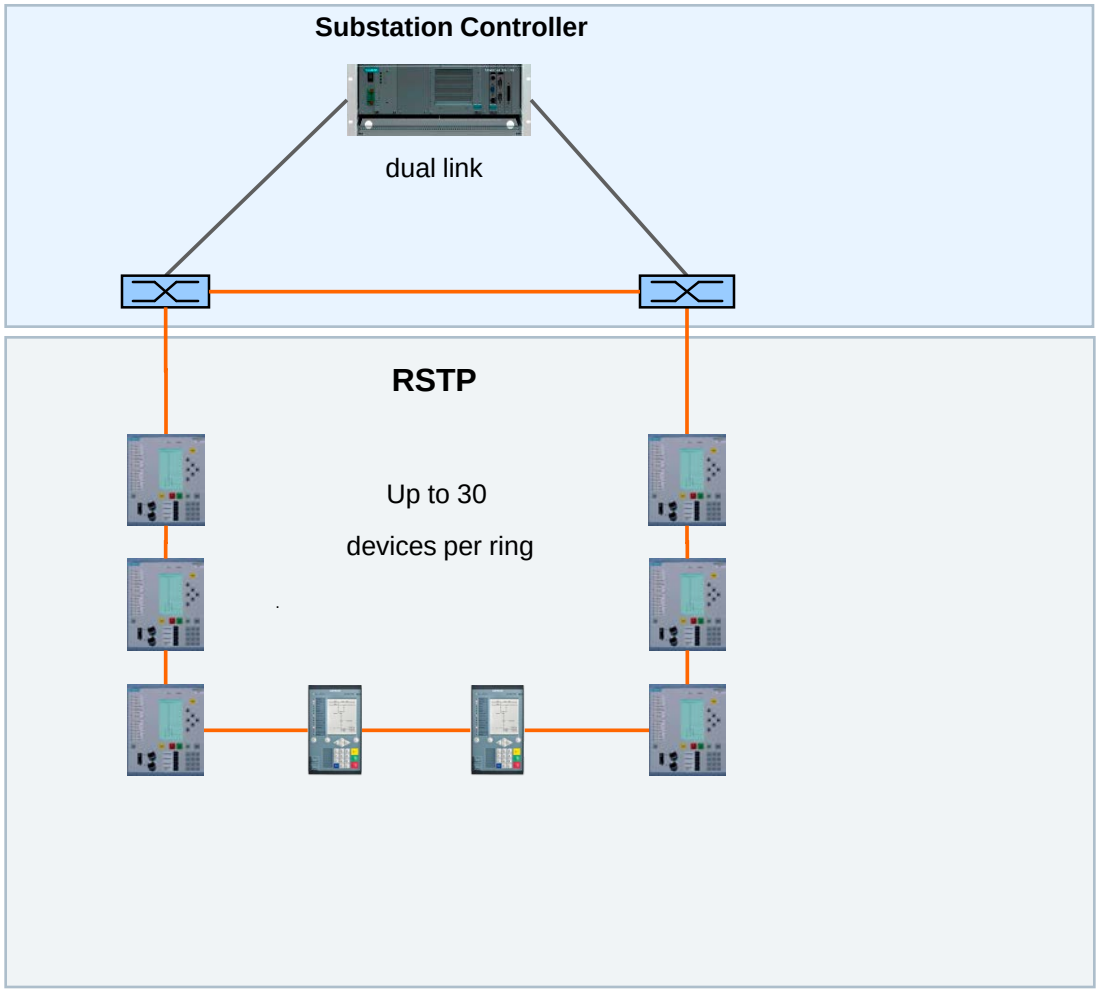
PRO

- Easy to handle
- No settings
- Huge field experience

CONS

- External switches required due to star structure
- Double number of external switches required
- Only supervision of directly linked connections

Principle of RSTP-Configuration



- 2 external RSTP-Switches
- Devices with integrated RSTP switch
- Rings with up to 30 devices
- Several rings can be connected to external switches
- Setting of RSTP parameters necessary

→ Well established technology (> 250.000 devices)

→ Field proven interoperability

RSTP Switch

RSTP over Fast fibre optic Ethernet

Features of RSTP

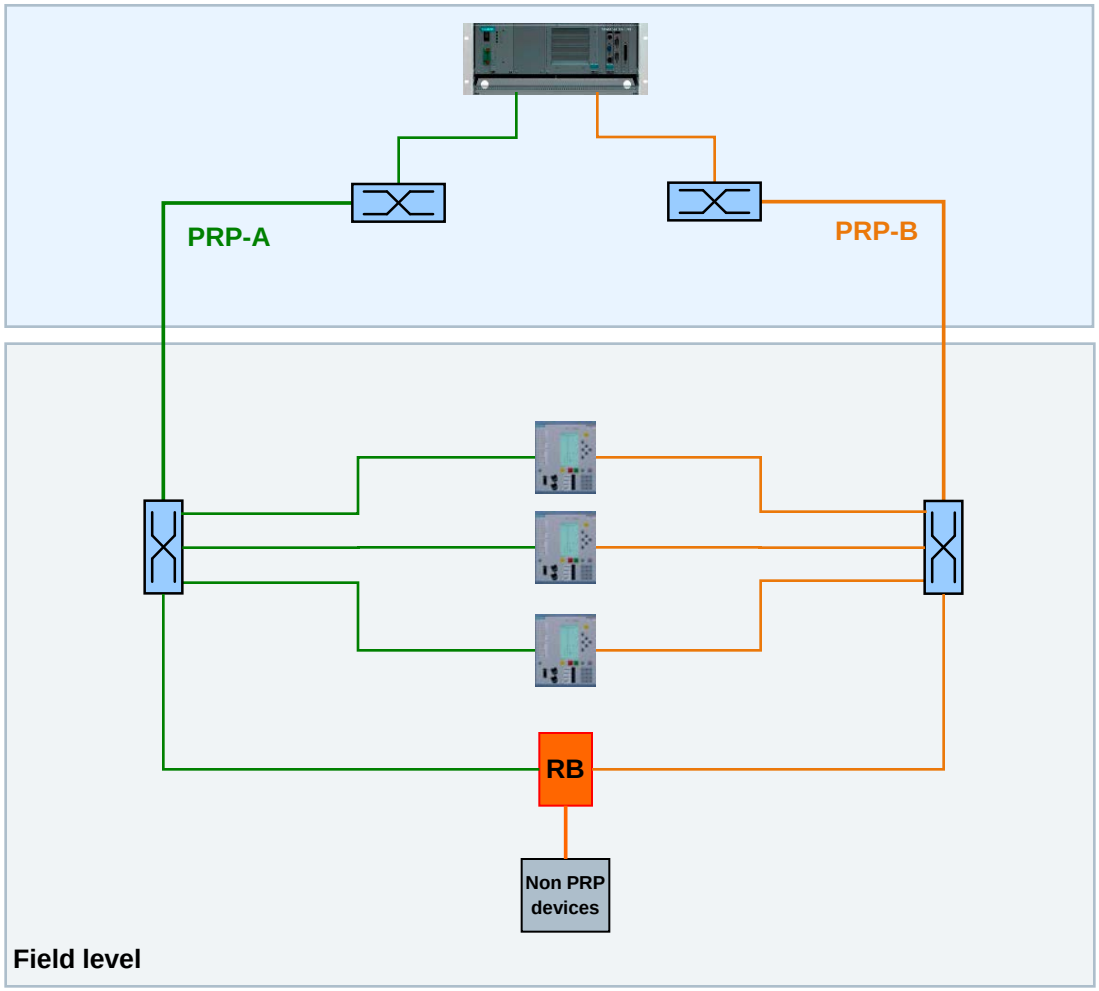
PRO

- Only one network required
- Redundancy achieved ring structure
- Huge field experience
- Approved IEEE 802.1D-2004 Standard

CONS

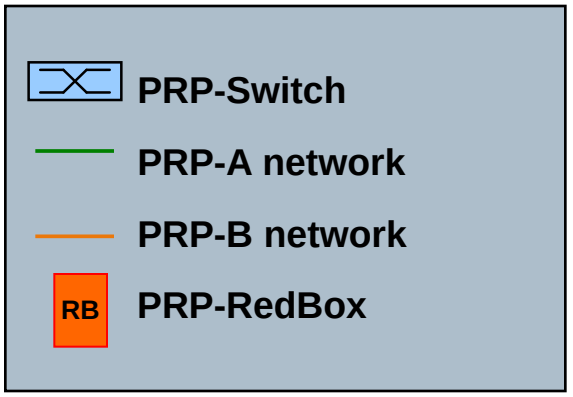
- Short reconfiguration time in case of interruption (dependent from failure location)
- Settings within RSTP switches necessary

Principle of PRP



- Two parallel networks
- Device are connected to network PRP-A and PRP-B
- Devices send via both active links
- RedBox for connection of non PRP devices
- Seamless

→ Interoperability tests done



Details of redundancy principles
Features of PRP

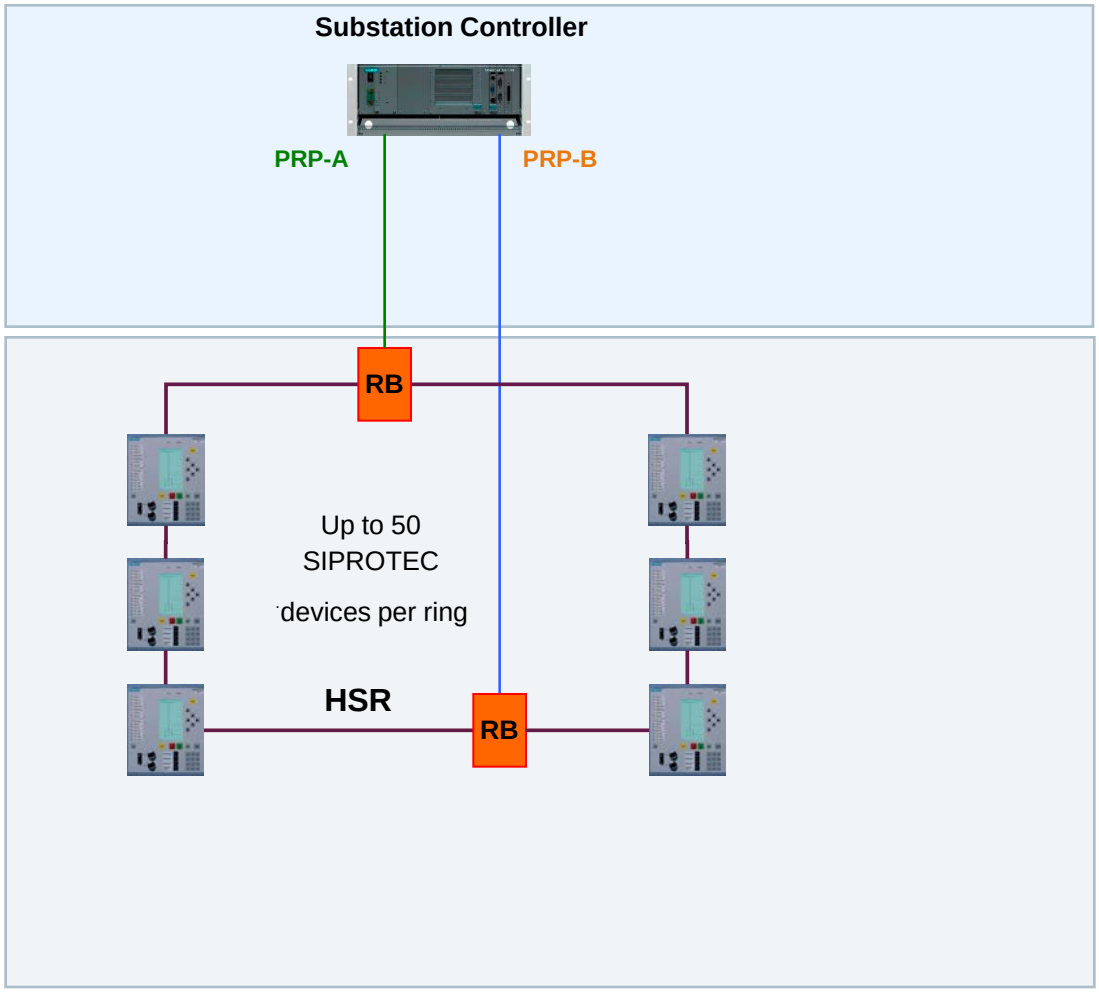
PRO

- Seamless reconfiguration - No recovery time
- Highest level of redundancy
- Simple mechanism, no special switch settings (as in RSTP)
- “normal” Devices with 1 interface can be connected to one of the PRP-Lan’s (SAN = Single attached nodes)
- Approved IEC Standard

CONS

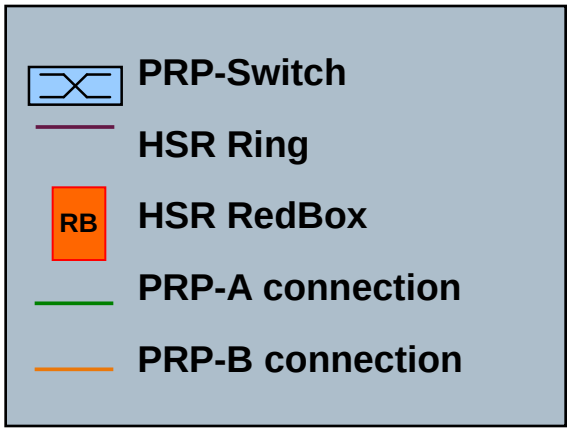
- Double number of switches = increased cost
- Switches have to handle Jumbo-Ethernet frames

Principle of HSR-Configuration



- 2 Redboxes
- Devices with integrated HSR switch
- Rings with up to 50 devices
- Redboxes distributed in the ring
- Seamless

→ Interoperability tests done



Features of HSR
High Available Seamless Redundancy

PRO

- Seamless reconfiguration - No recovery time
- One common Network
- cost reduction through ring configuration
- Single attached nodes can only be connected to the HSR network via a RedBox
- Approved IEC 62439-3 Standard

CONS

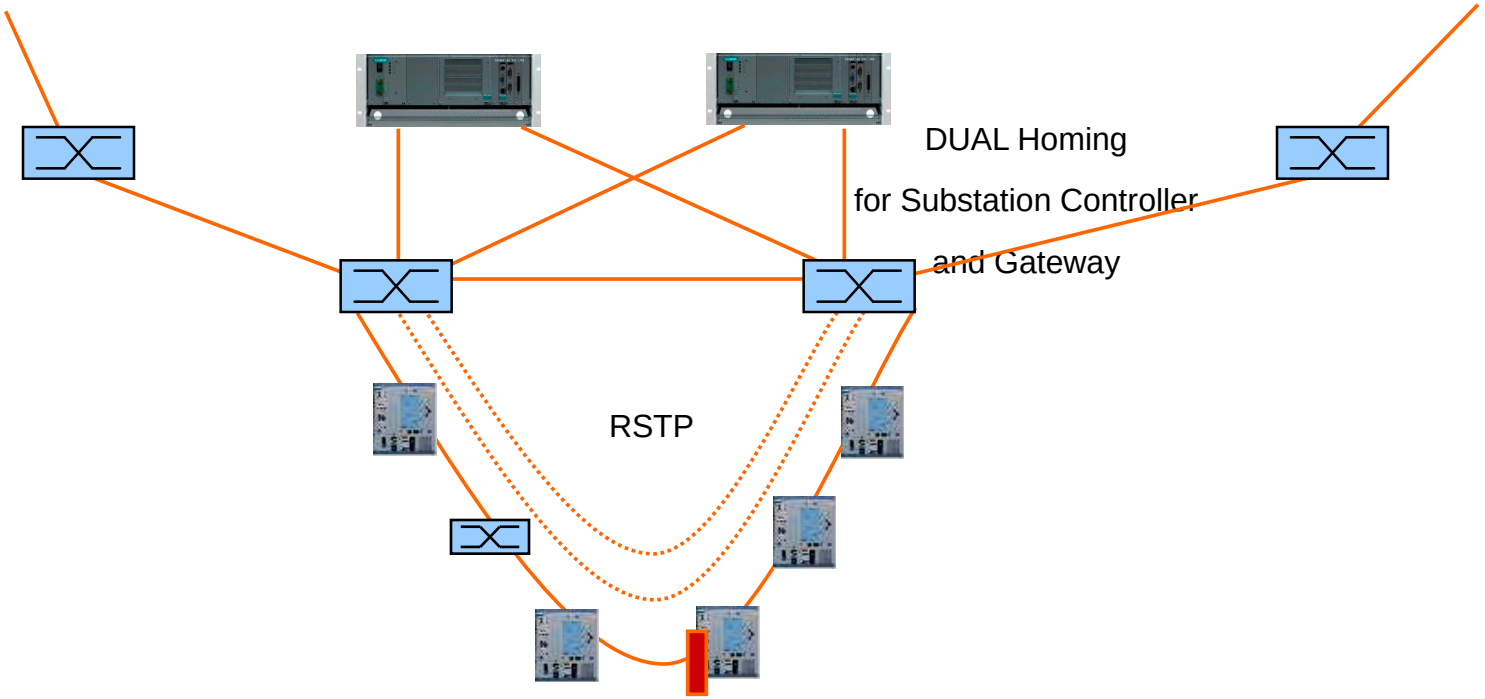
- Standard Ethernet components (e.g. PC) can be connected only via a RedBox

Comparison of redundancy mechanisms

	RSTP	PRP	HSR
Network configuration	ring	parallel	ring
Max. devices per layer 2 network	Unlimited (max. 30 / ring)	512	512 (max. 50 / ring)
Seamless (no recovery time)	-	✓	✓
Parameter free	-	✓	✓
Budget-saving network	✓	-	✓

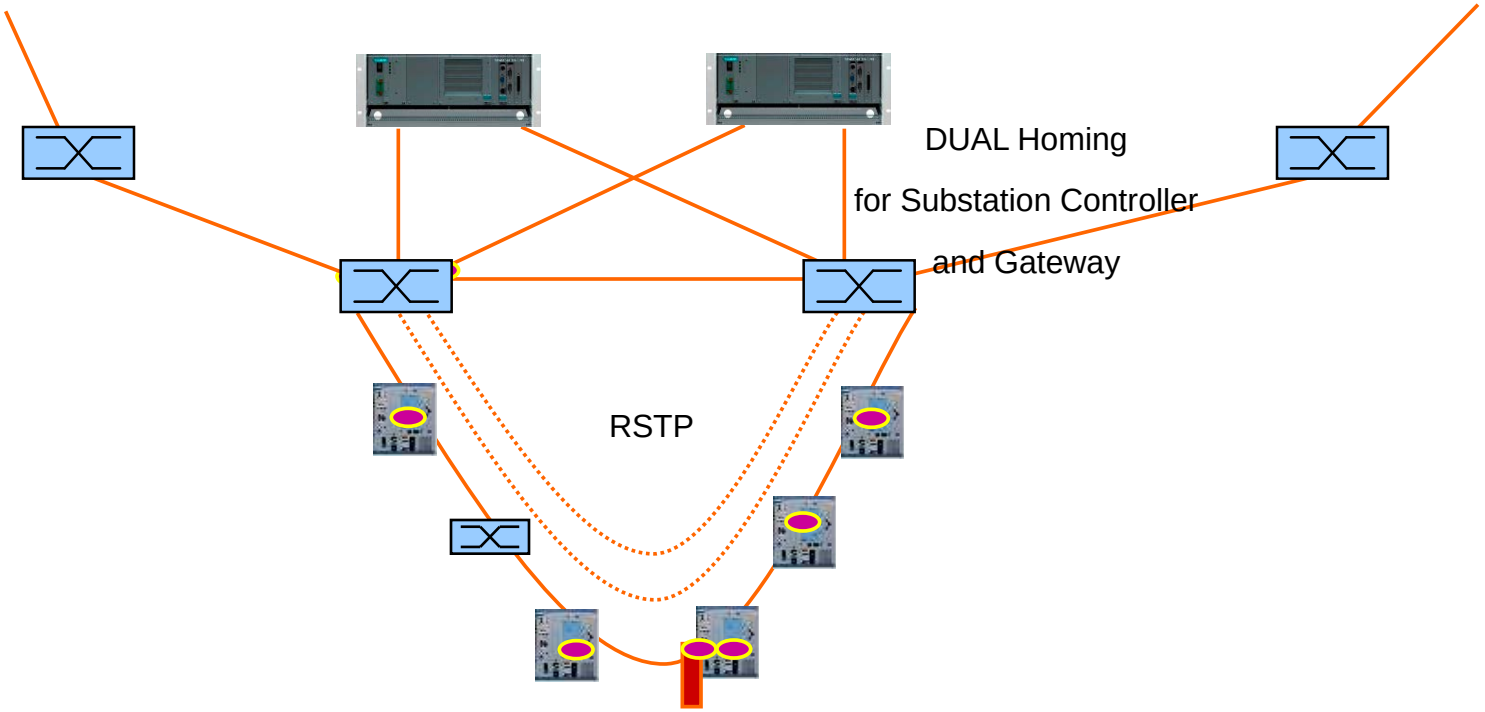
Details of redundancy principles
RSTP with IED integrated cut- through switches

- **Normal operation**



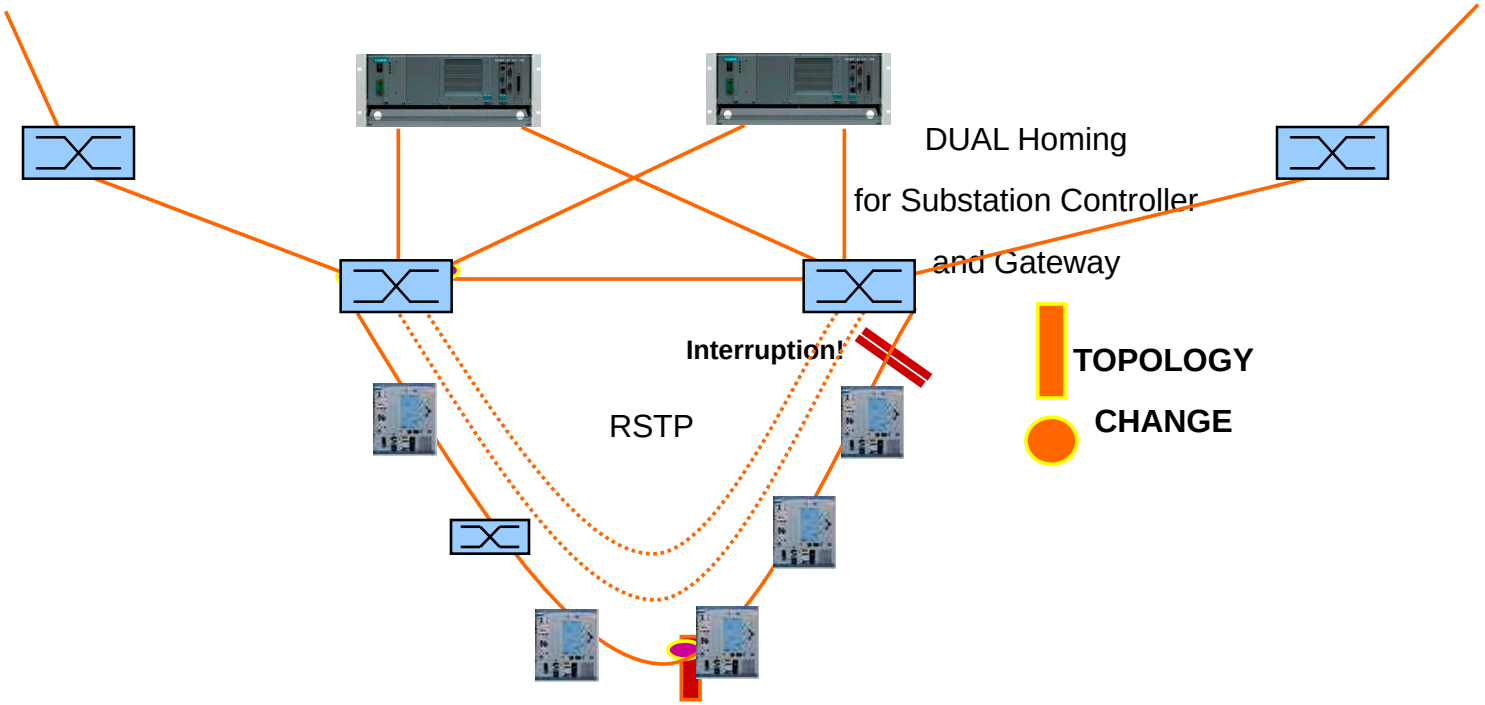
Details of redundancy principles
RSTP with IED integrated cut- through switches

- **Topology constantly monitored by peer to peer bridge PDU's**



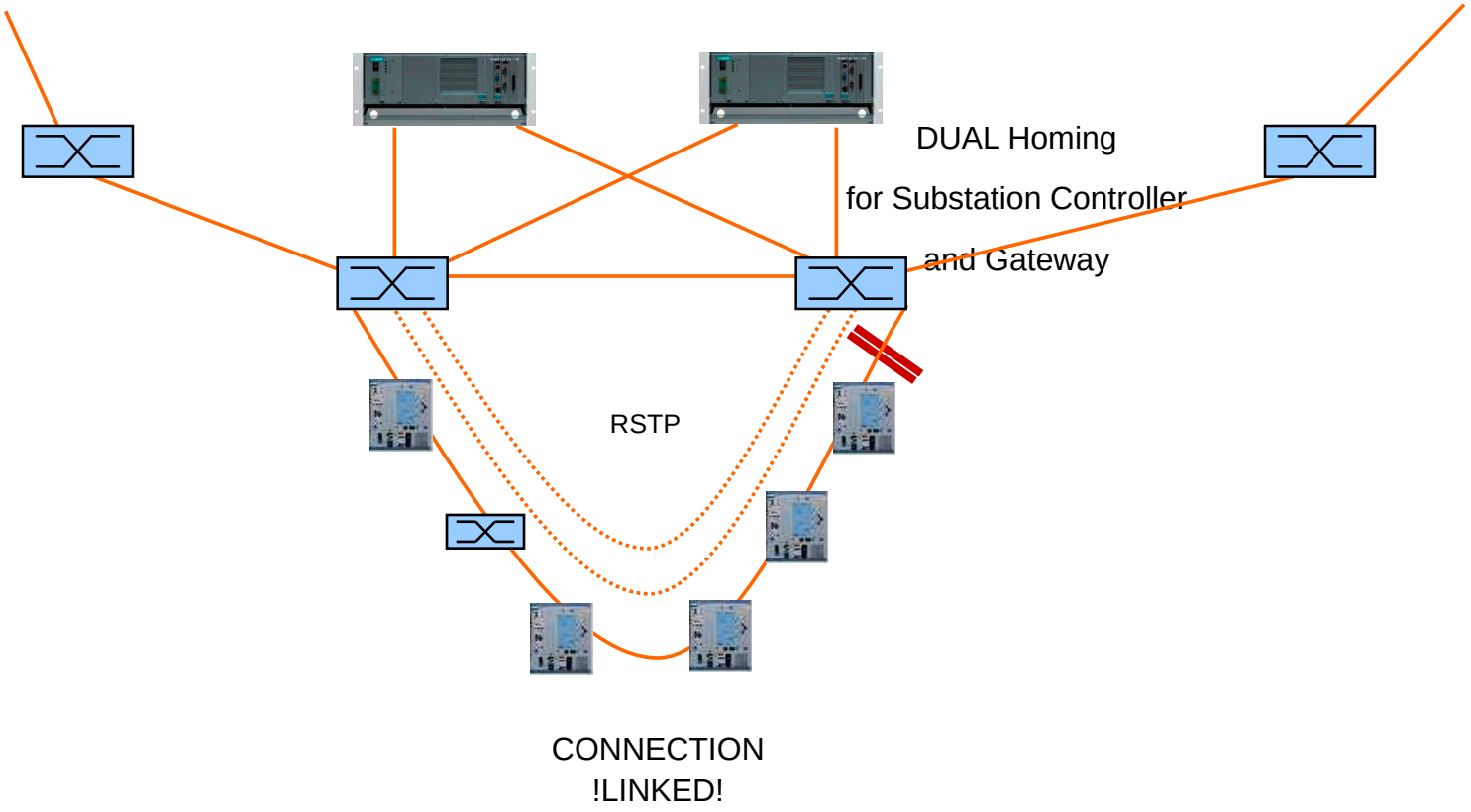
Details of redundancy principles
RSTP with IED integrated cut- through switches

- **Interruption with topology change**

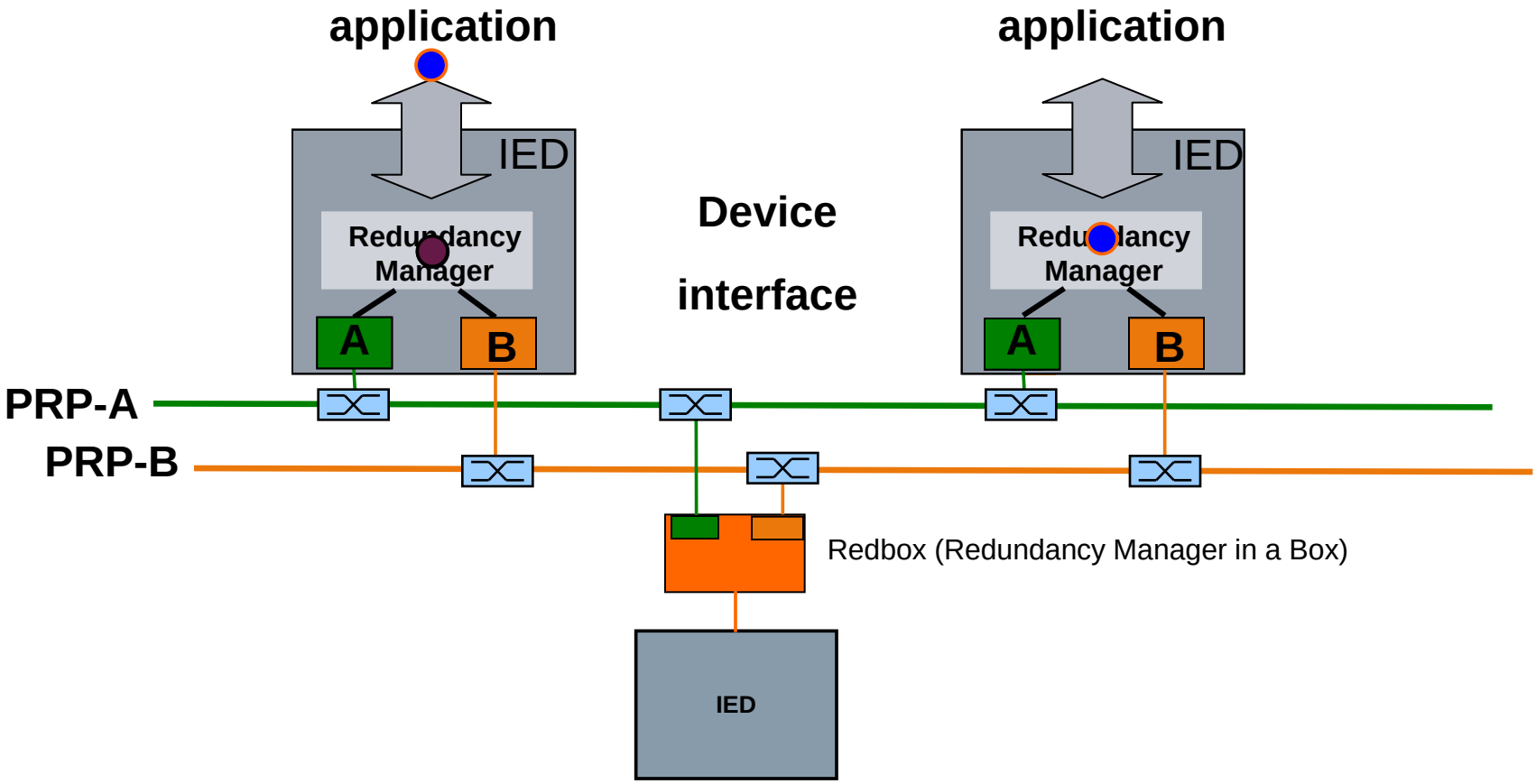


Details of redundancy principles
RSTP with IED integrated cut- through switches

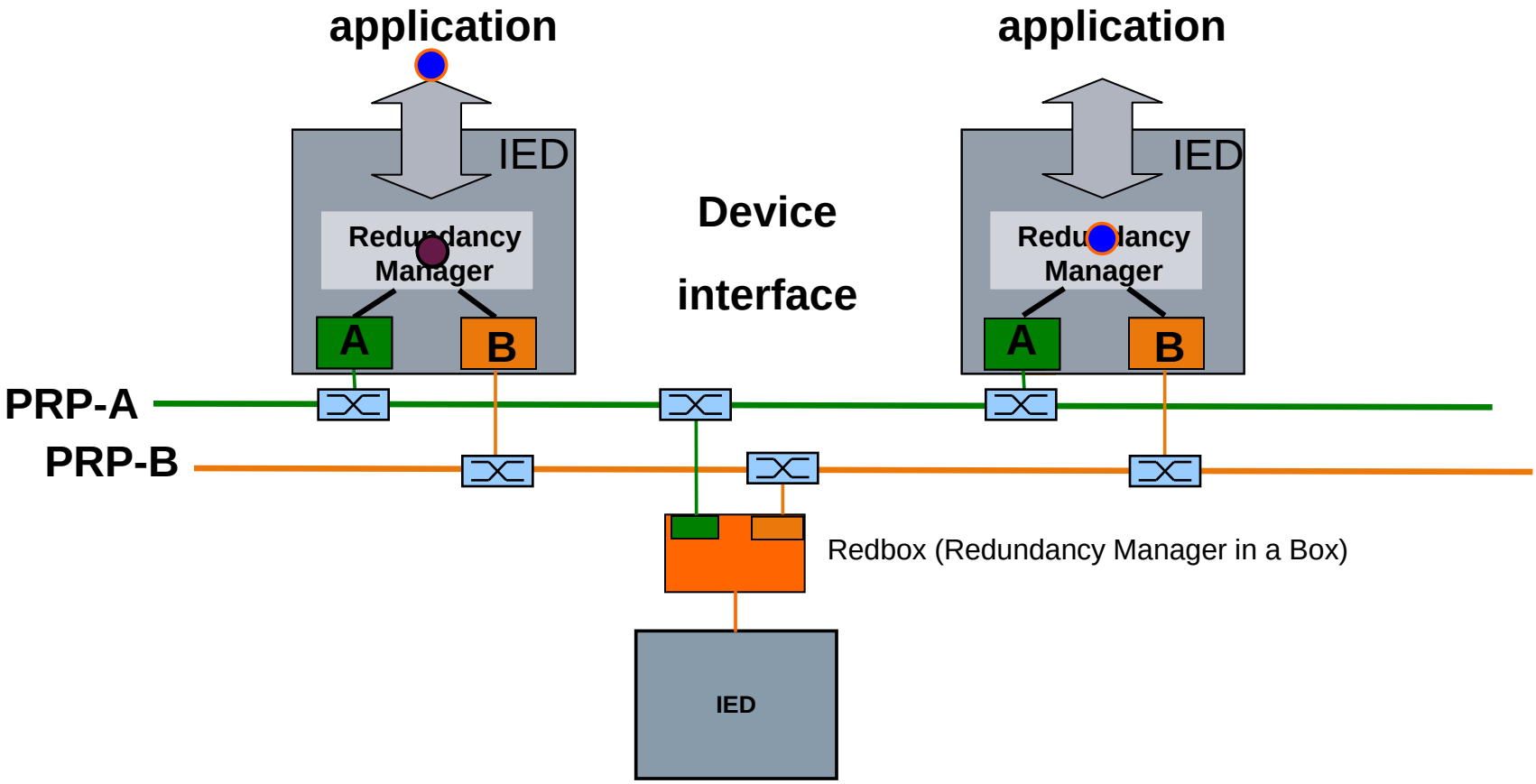
- **New topology after interruption**



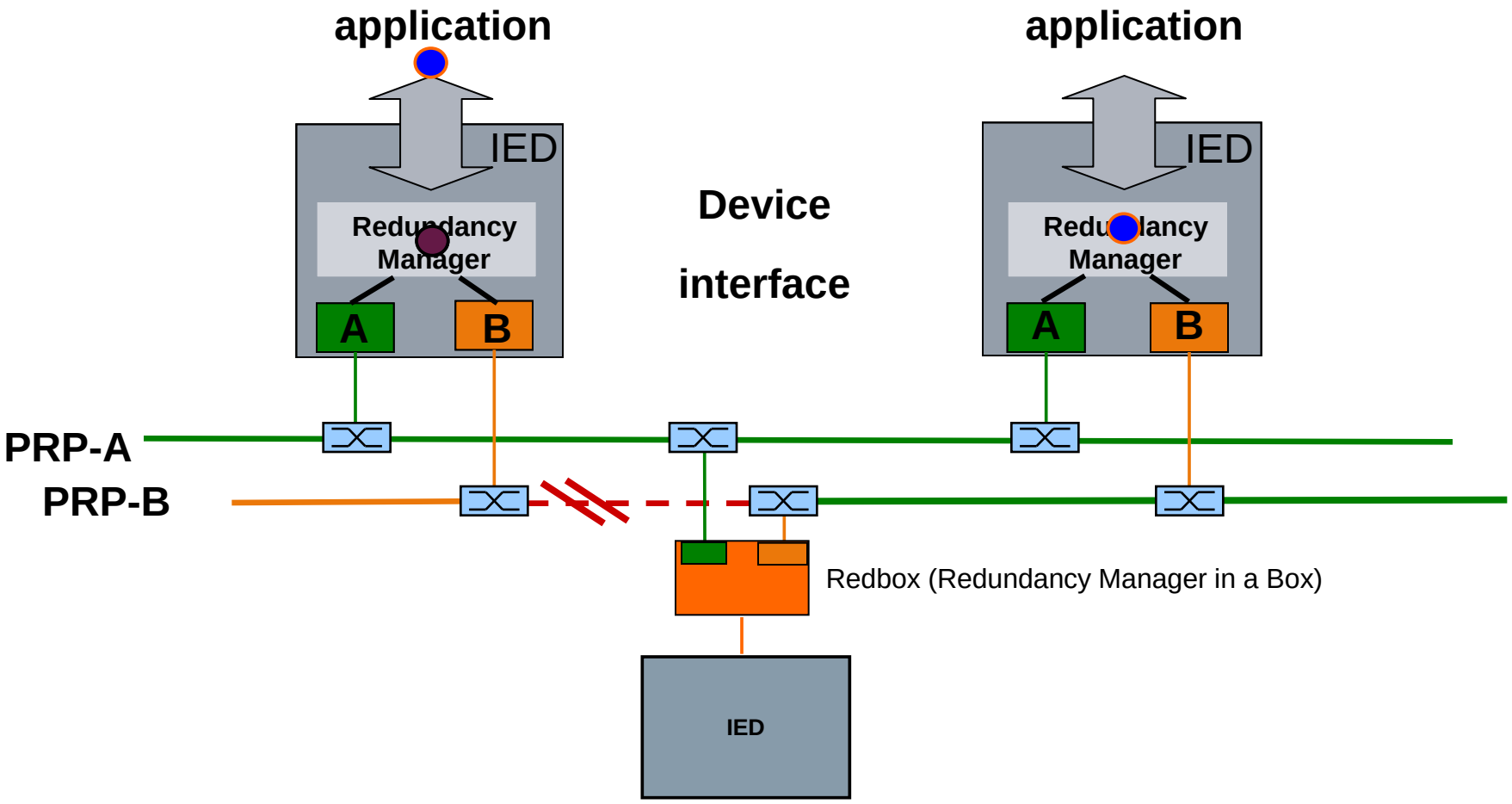
Details of redundancy principles
PRP normal operation



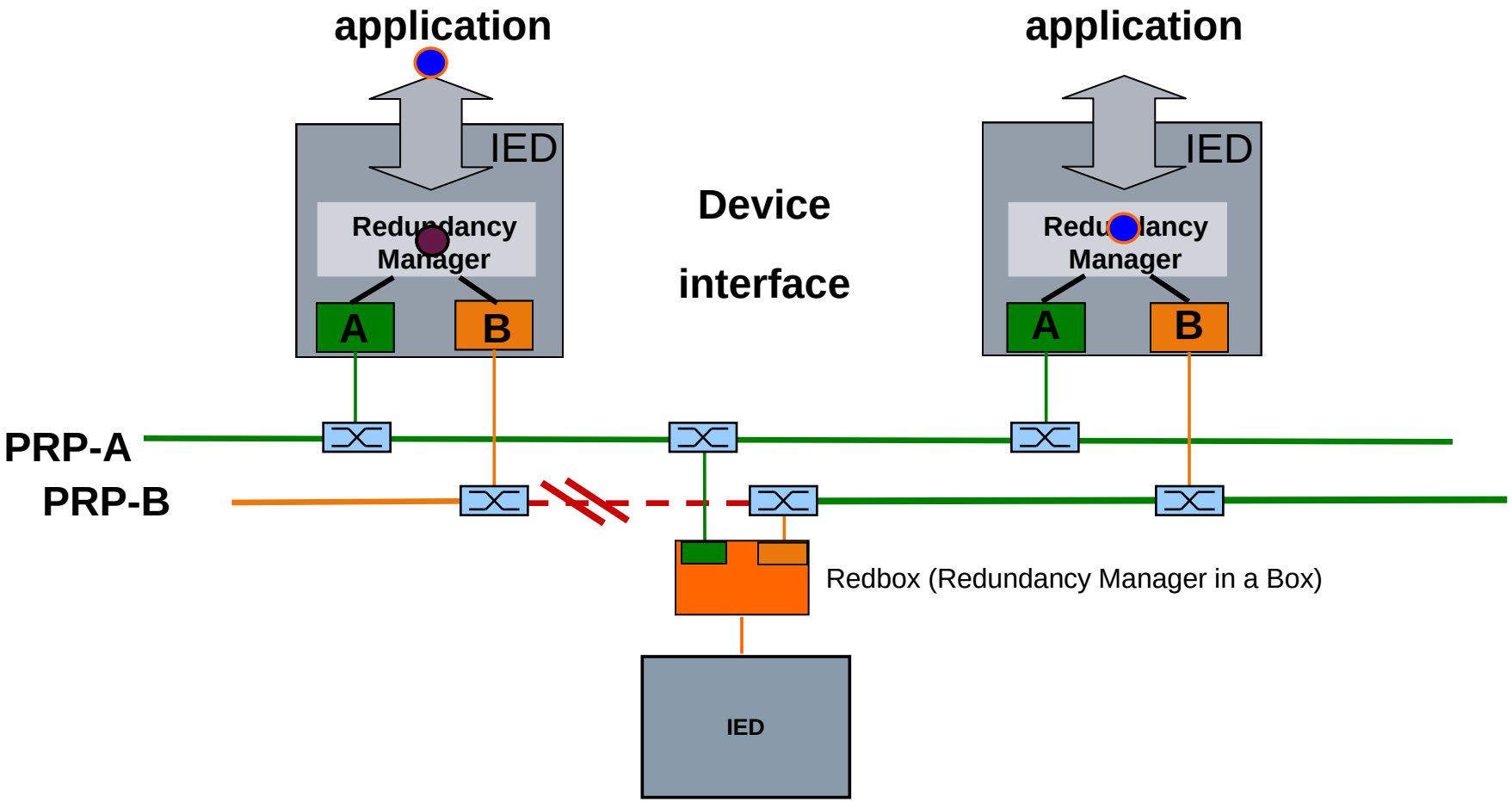
Details of redundancy principles
PRP normal operation



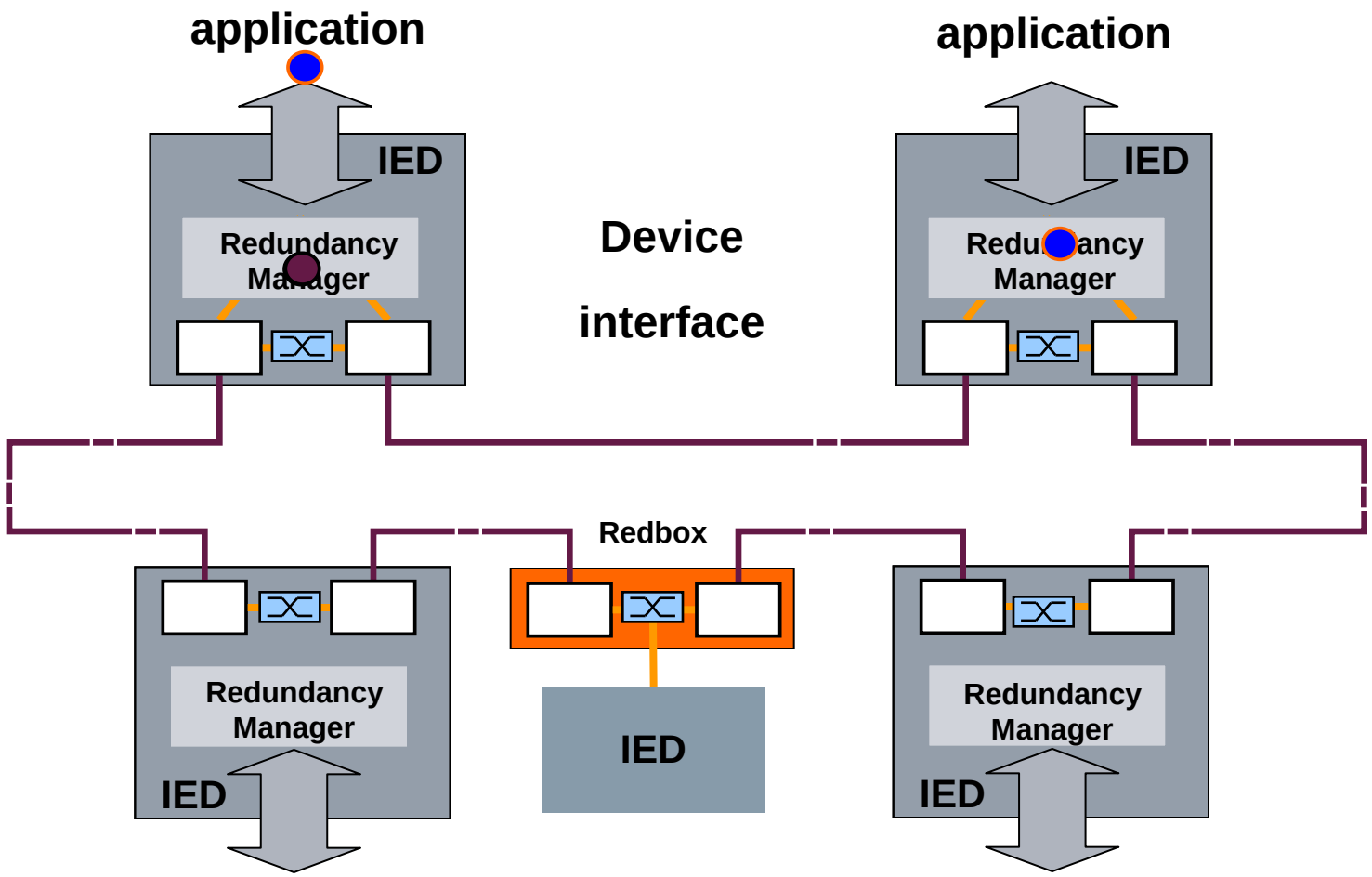
Details of redundancy principles
PRP, case of n-1



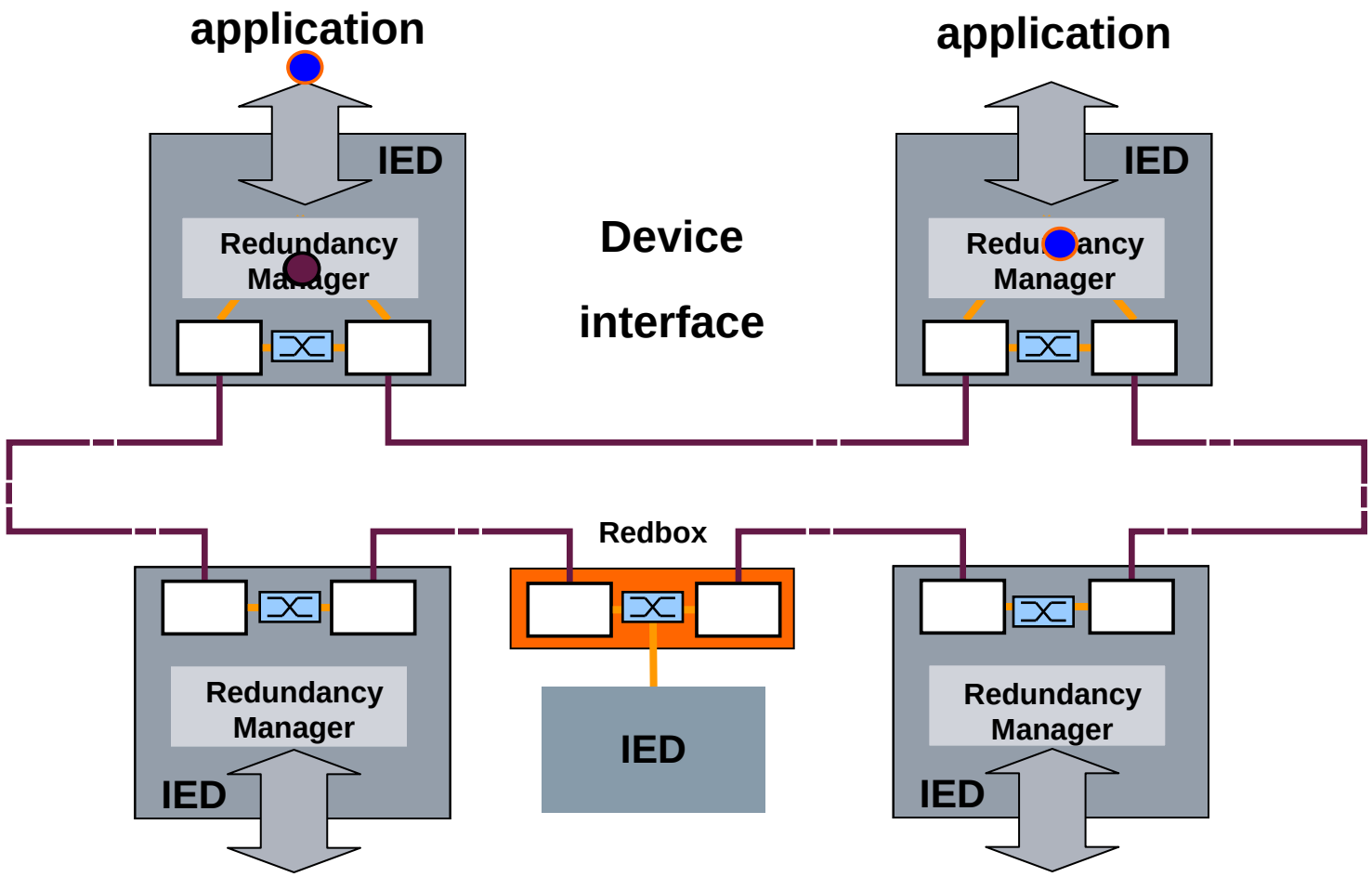
Details of redundancy principles
PRP, case of n-1



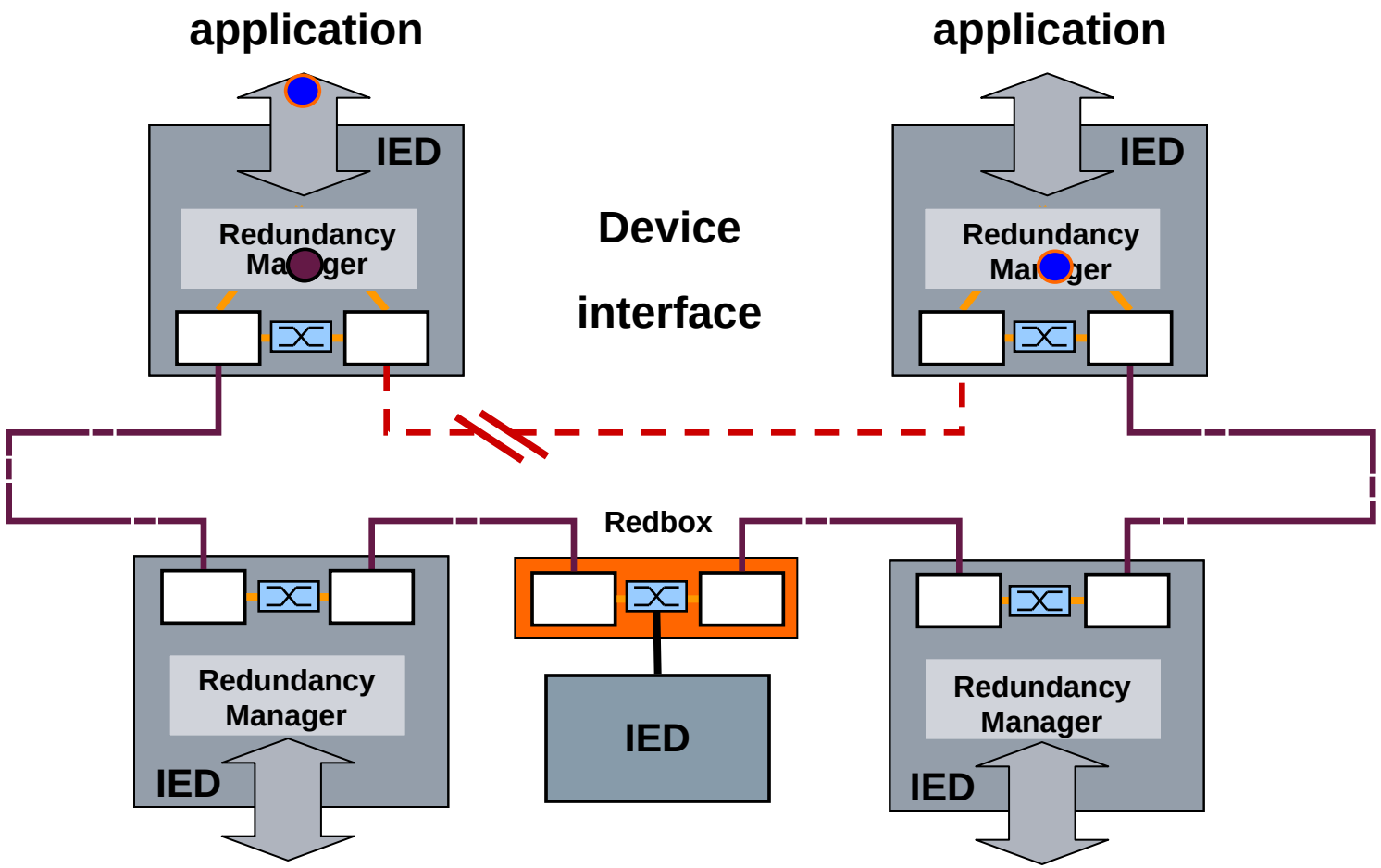
HSR –
High Available Seamless Redundancy Principle



HSR –
High Available Seamless Redundancy Principle



Details of redundancy principles
HSR – High Available Seamless Redundancy Principle



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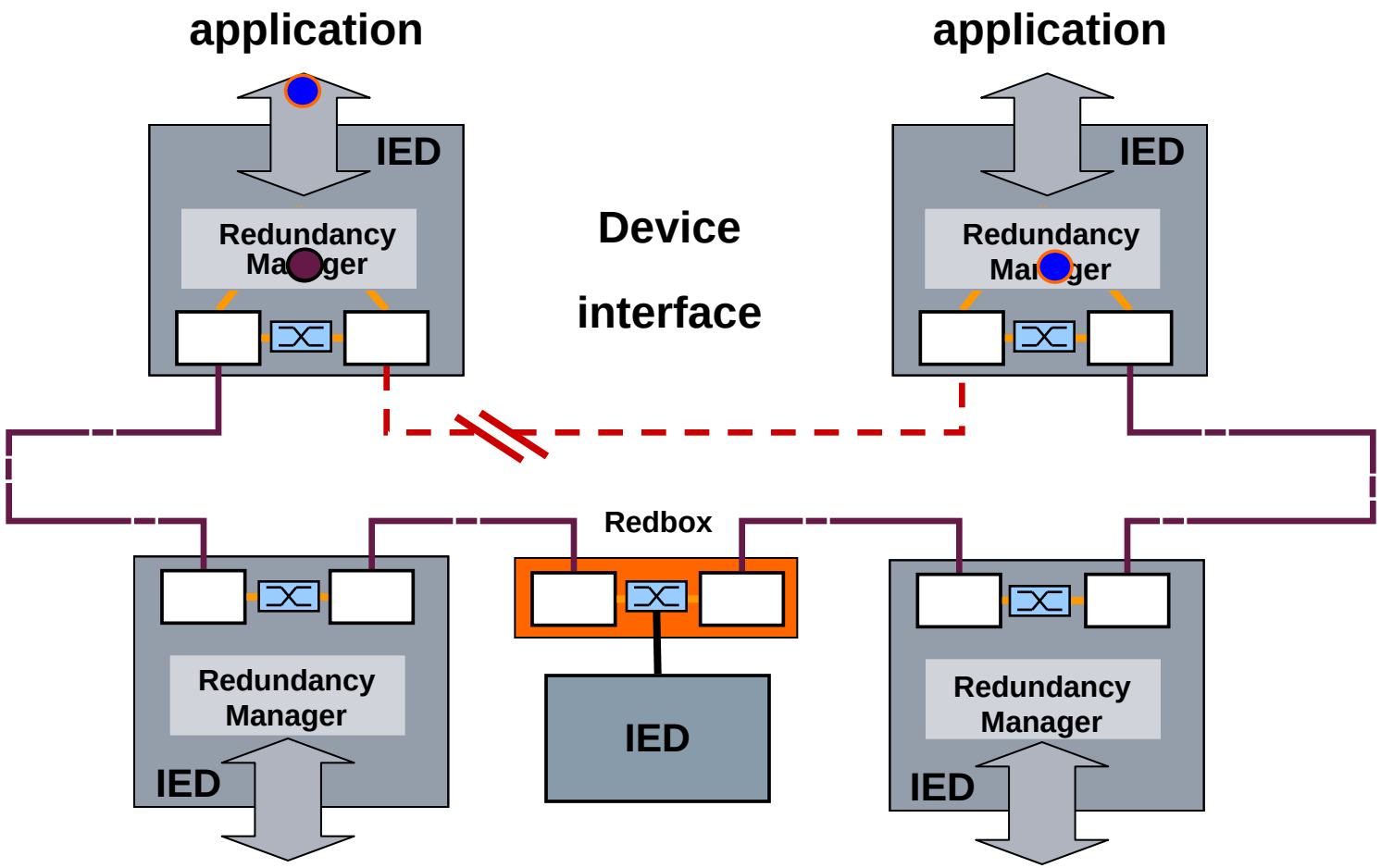
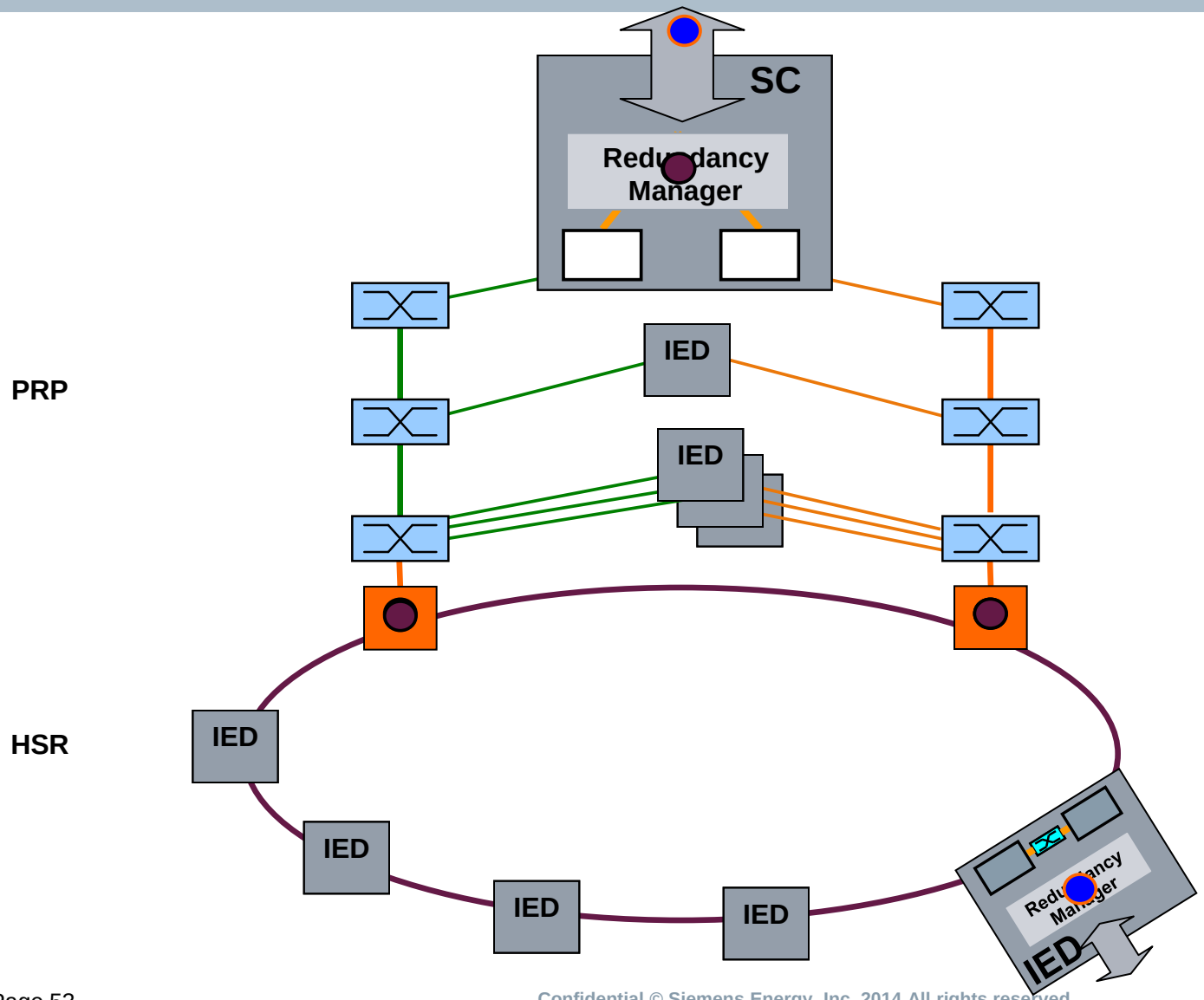
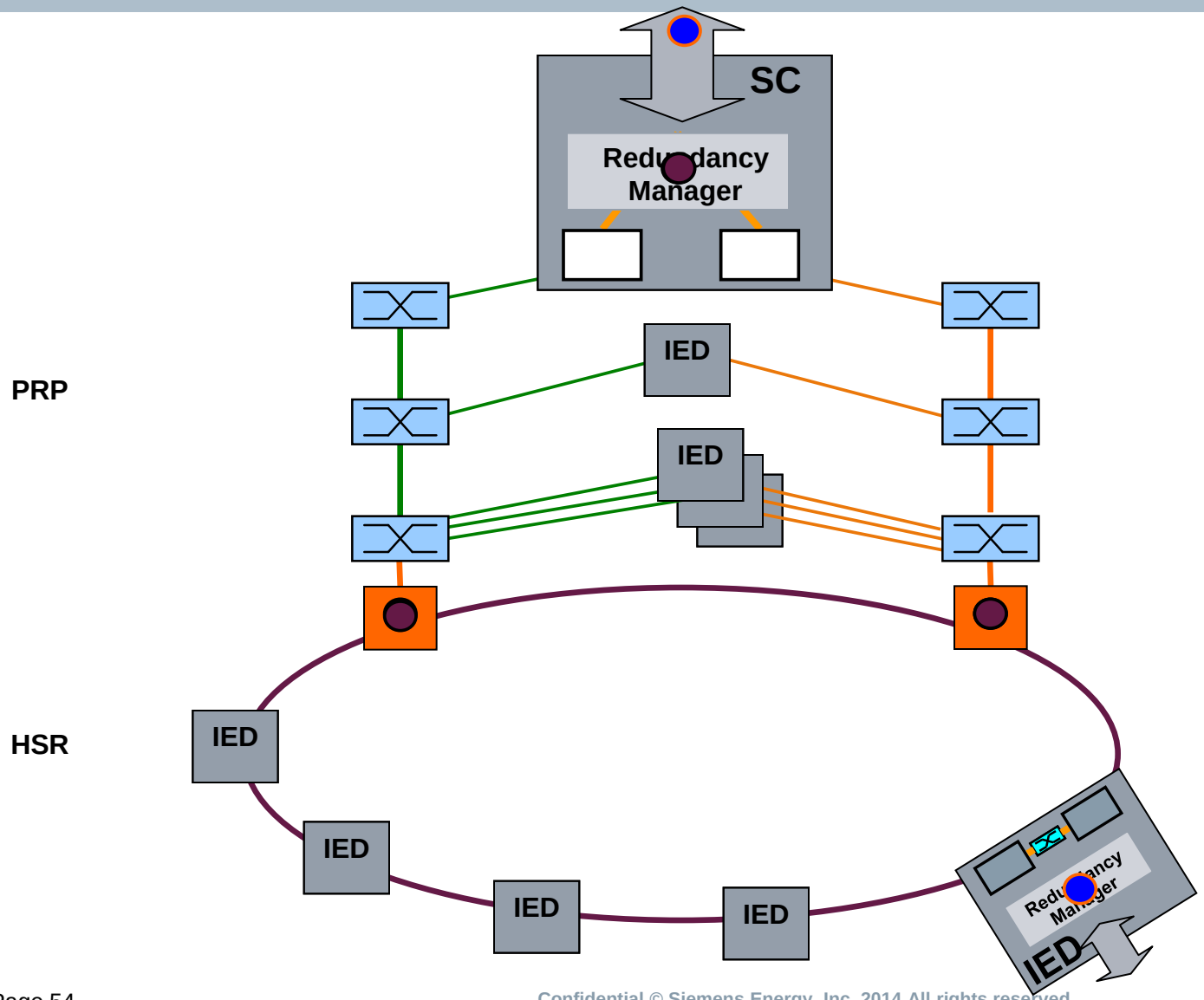
HSR – High Available Seamless Redundancy Principle



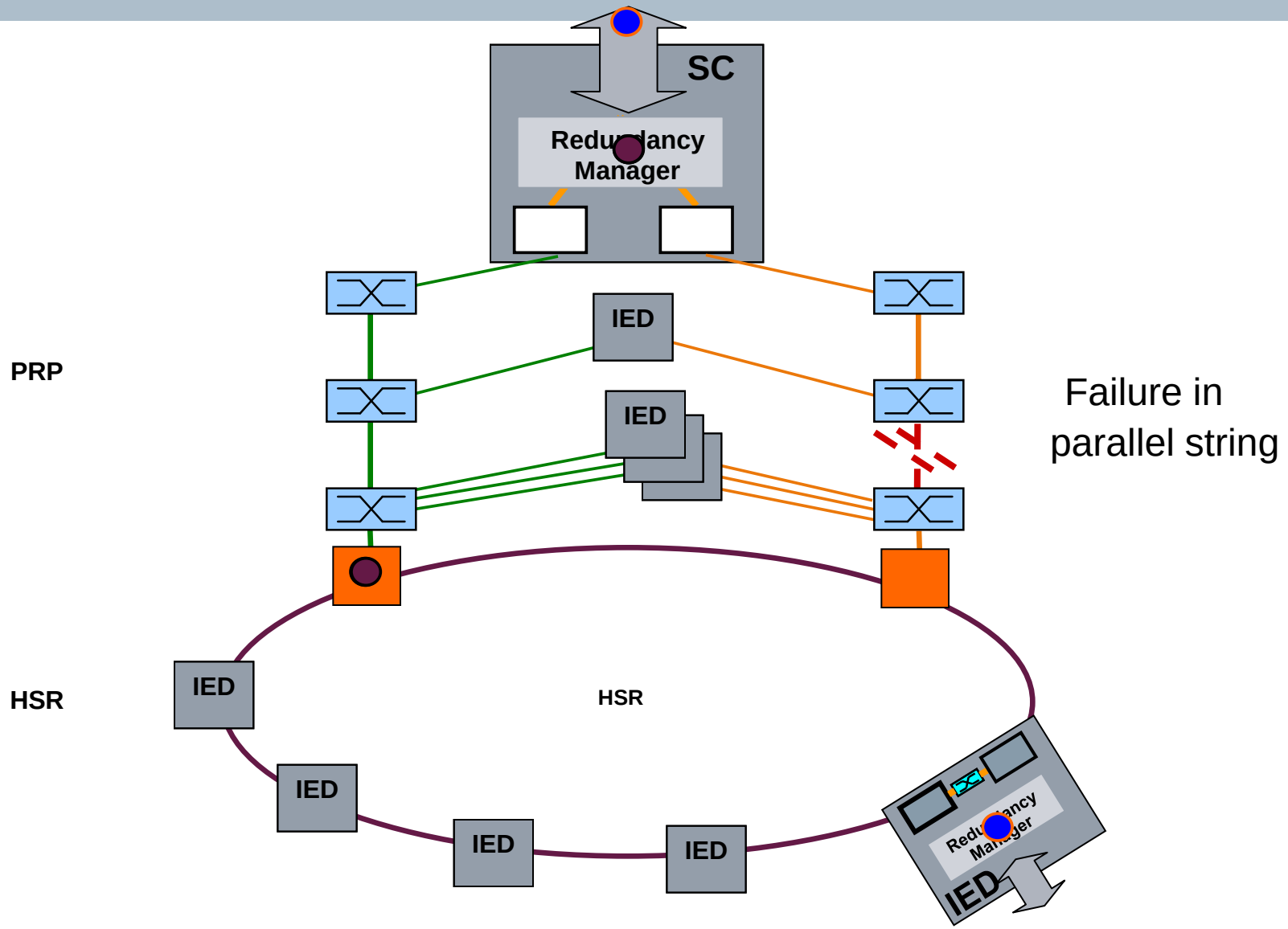
Details of redundancy principles
PRP/HSR in Parallel and Ring Redundancy



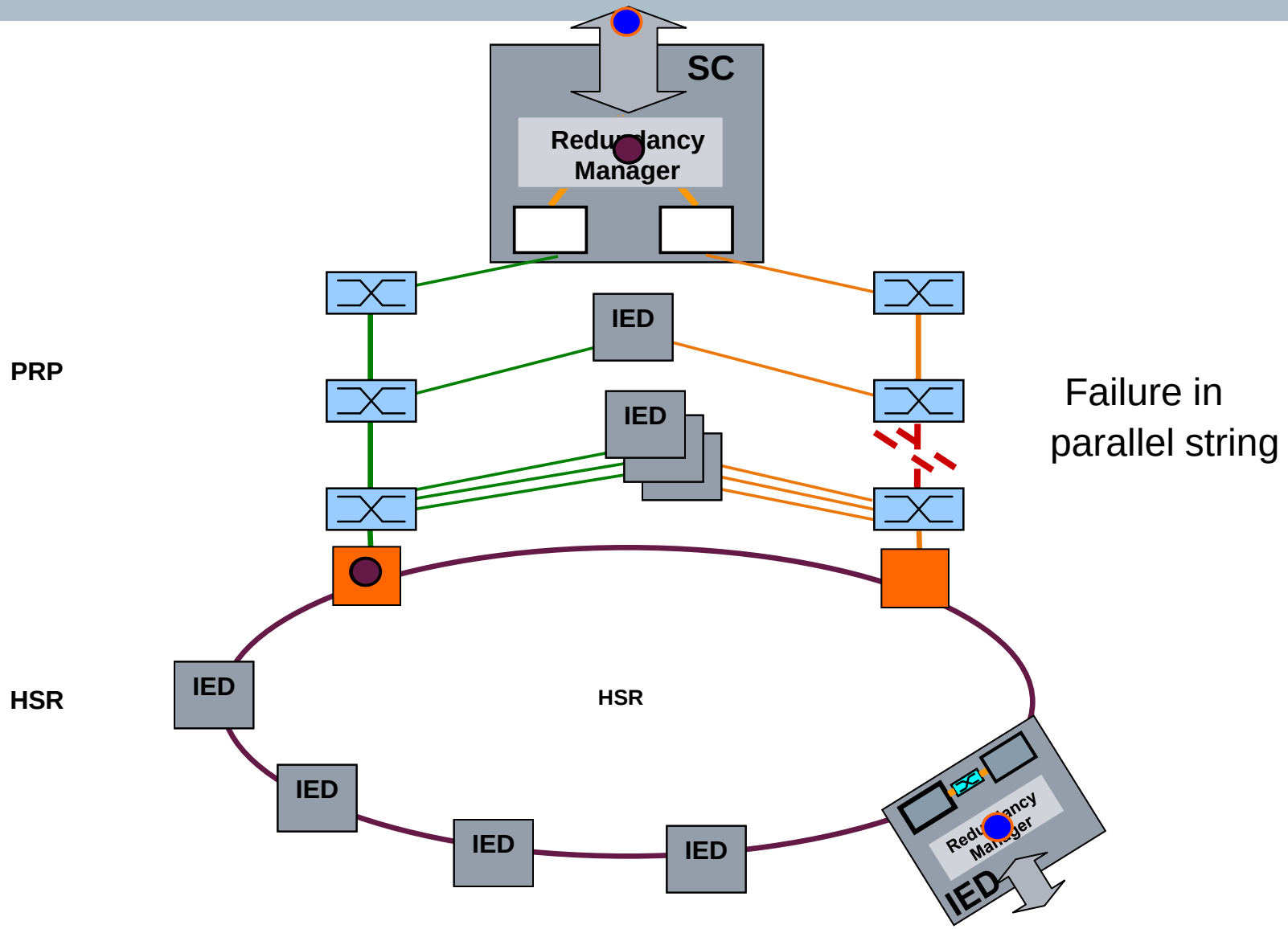
Details of redundancy principles
PRP/HSR in Parallel and Ring Redundancy



Details of redundancy principles PRP/HSR in Parallel and Ring Redundancy



Details of redundancy principles PRP/HSR in Parallel and Ring Redundancy



Example Network Architecture
Industrial Power Management Systems