

# IEEE 1588 v2 and High Availability Seamless Redundancy : New Technologies for Smart Grid Information Networks



## What is IEEE 1588 v2?

- ❑ A “new” Network based Precision Time Protocol
- ❑ Designed to address Smart Grid requirements and the weaknesses of NTP
  - Accuracy
  - Scalability
  - Cost

IEC 61850 Edition 2

IEEE 1588 Version 2

Power Profile

- (PSRC PC37.238)

IEC 62439-3 Highly Available Automation Networks

RSTP – Rapid Spanning Tree Protocol

PRP – Parallel Redundancy Protocol

HSR – High Availability Seamless Redundancy

Designed for increased time accuracy and reduced complexity / cost for IEDs:

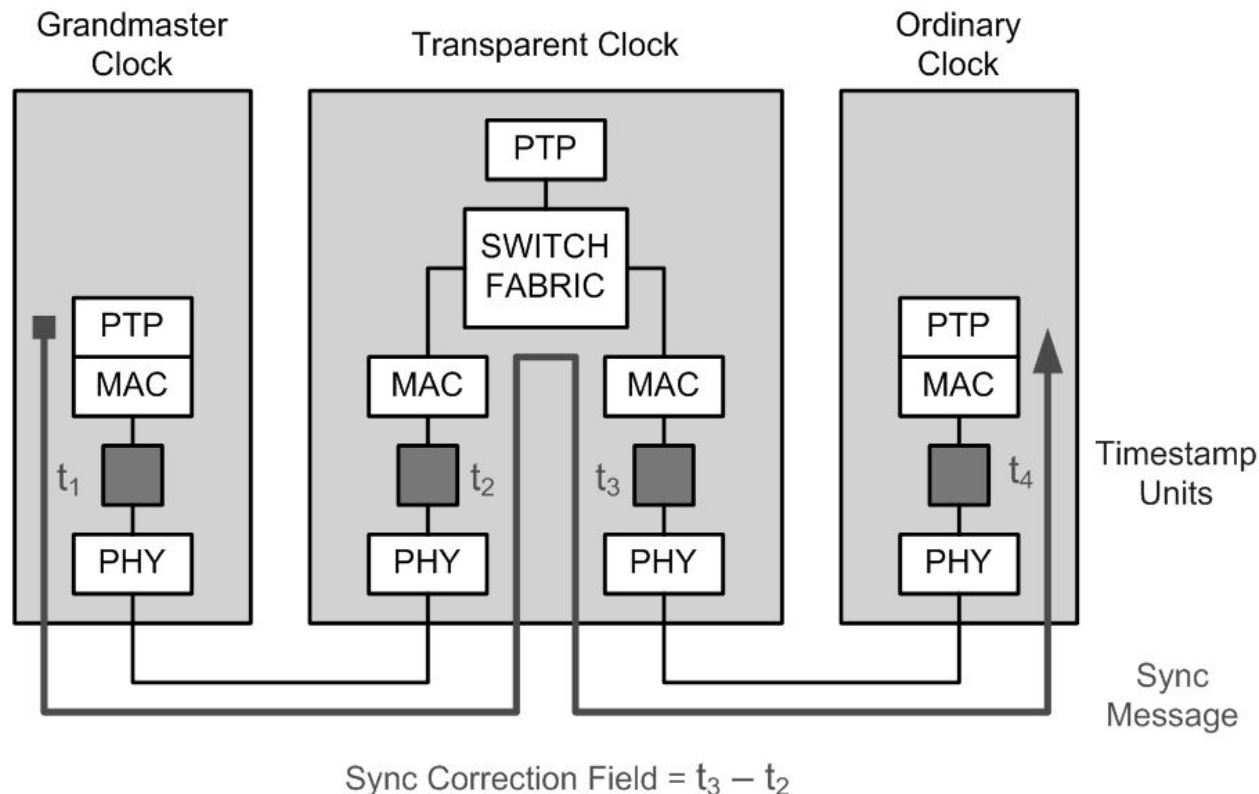
- Accuracy: 1us over 16 network hops
- 1 sync signal per second
- Layer 2 Multicast

- It eliminates the extra cabling requirements of 1PPS or IRIG-B to propagate highly accurate timing signals
- More accurate than IRIG-B or SNTP
- Required for:
  - Process Bus
  - Synchrophasors
  - Reliability

Method	Typical Accuracy in substation with given method	Provides date and time of day indication	Dedicated cabling not required	Cost effective	Scales well with large number of devices
IRIG-B (AM)	1ms	•			
IRIG-B (DC-shifted)	100us	•			
1PPS	1us				
GPS	1us	•			
NTP	1-10ms	•	•	•	
IEEE 1588 v1	1us	•	•	•	
IEEE 1588 v2	1us	•	•	•	•

## Comparing Precision Time Protocols

IEEE 1588 hardware assistance is placed between the PHY and MAC layer of an Ethernet device



- ❑ Path delay - how long it takes a message to propagate from the grandmaster to the slave
- ❑ Many delays are introduced on the path including:
  - Cable delay
  - Encoding and decoding of symbols on the wire
  - Switch fabric latency
  - Store and forward of switches
  - Queuing from switches

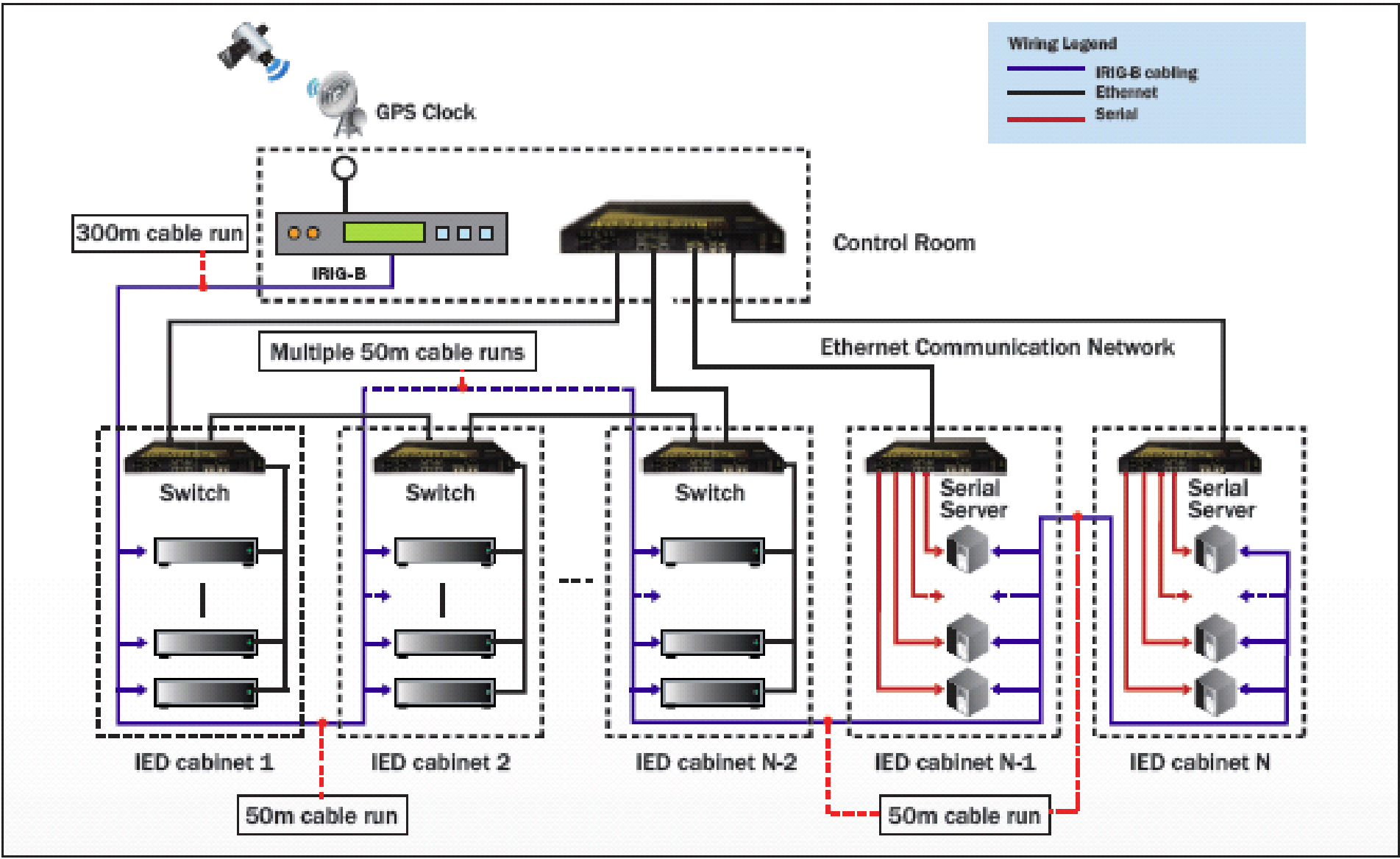


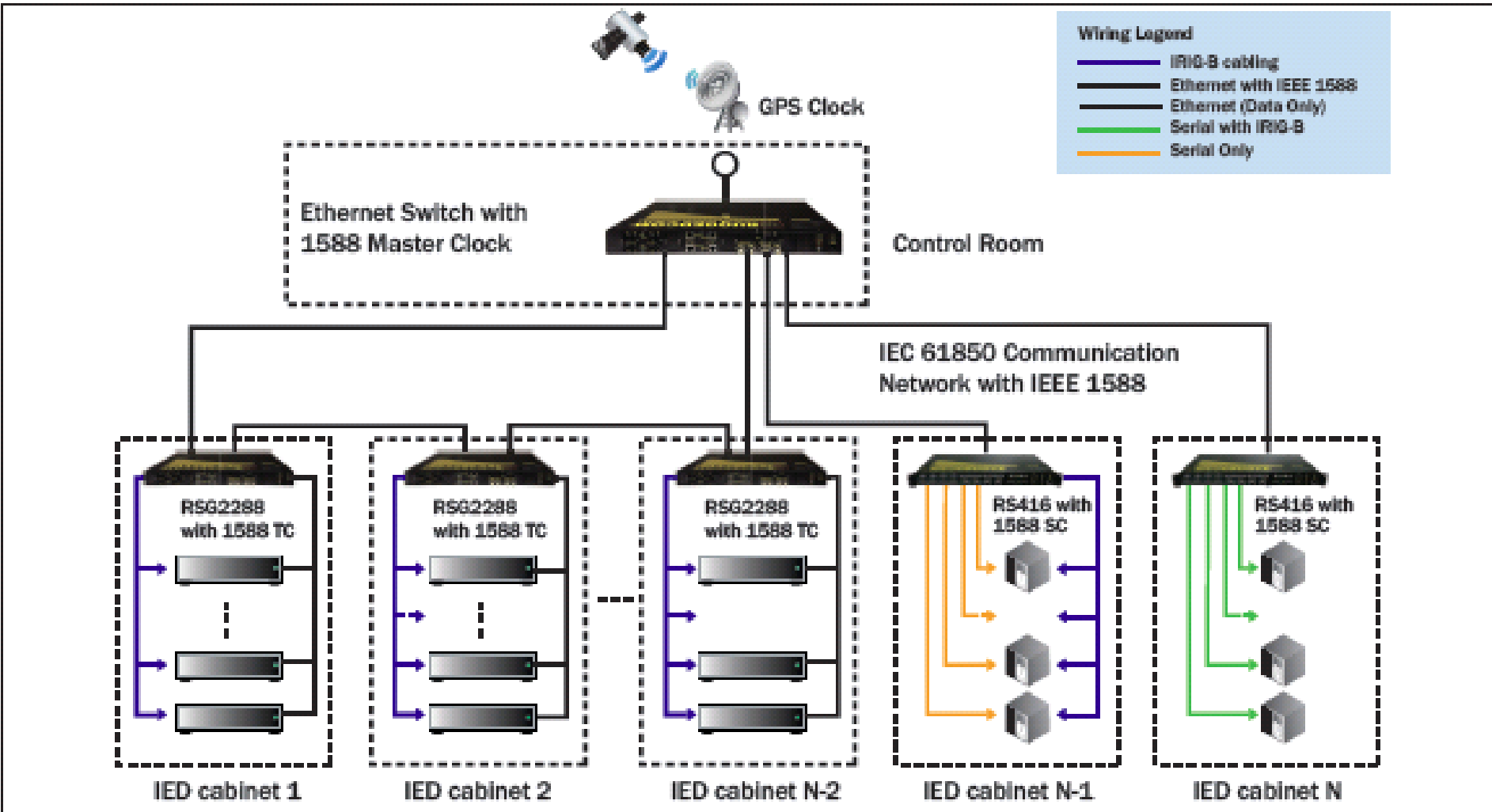
First installations of IEEE 1588v2 high accuracy time synchronization in High Voltage Substations in China based on IEC61850 Process Bus

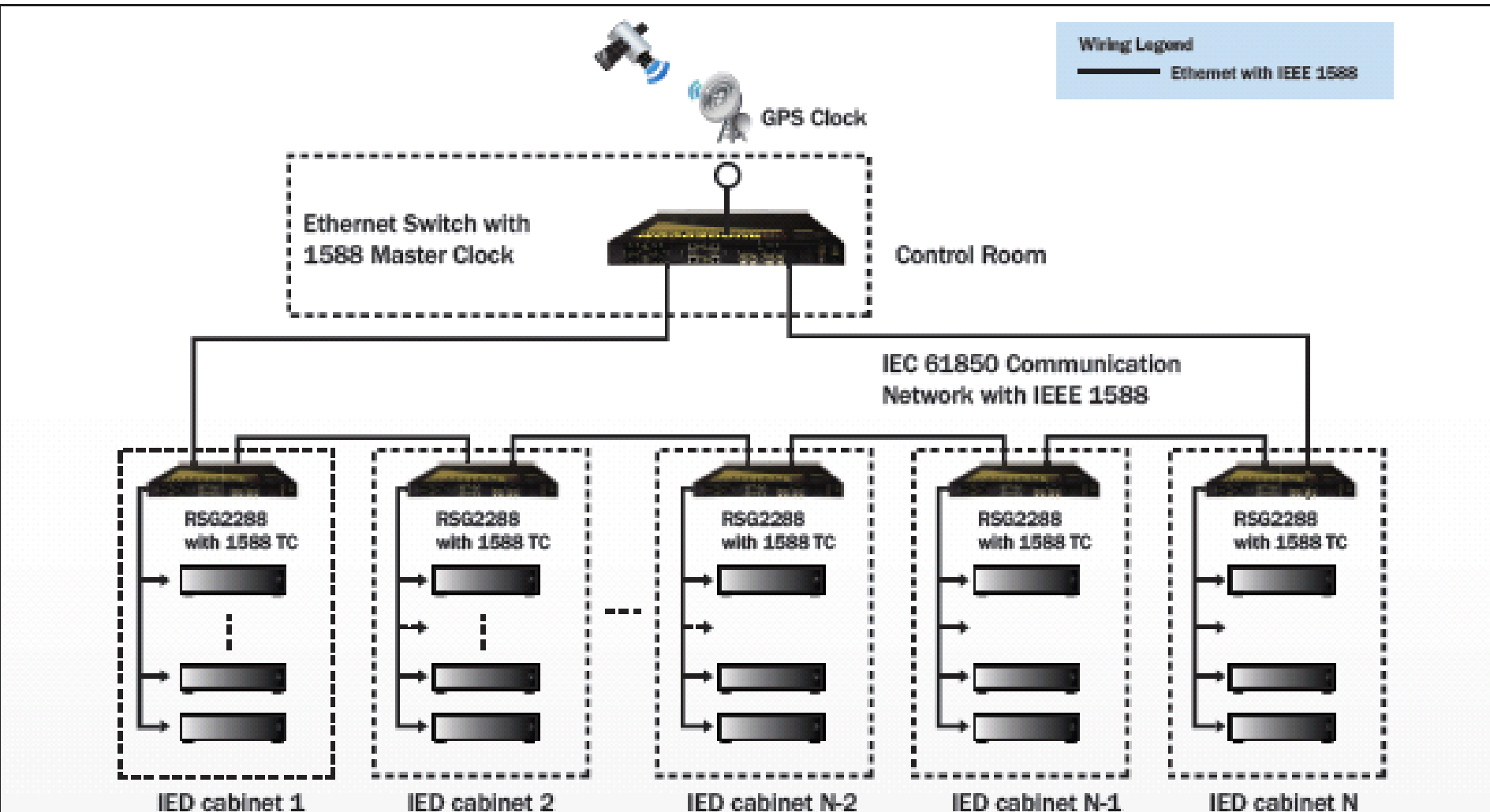
North America: conversion of utility IRIG-B network to IEEE 1588 v2

First installations of IEEE 1588v2 high accuracy time synchronization in High Voltage Substations in China based on IEC61850 Process Bus

North America: conversion of utility IRIG-B network to IEEE 1588 v2







## What is HSR?

- ❑ A “new” Ethernet high reliability protocol
- ❑ Designed to address industrial process control requirements / weaknesses of Ethernet
  - Redundancy / Failover
  - Latency
  - Predictability
  - Cost

## Standards: Promoting Interoperability!

- ❑ IEC 62439 “Highly Available Automation Networks”, ratified May 2008
- ❑ Describes several protocols with different characteristics: MRP, PRP, CRP, BRP, RSTP, HSR...
  - Vendor driven
  - No interoperability and performance varies
- ❑ HSR, PRP and RSTP included in 2010 Q1

IEC 61850 Edition 2

IEEE 1588 Version 2

Power Profile

- (PSRC PC37.238)

IEC 62439-3 Highly Available Automation Networks

RSTP – Rapid Spanning Tree Protocol

PRP – Parallel Redundancy Protocol

HSR – High Availability Seamless Redundancy

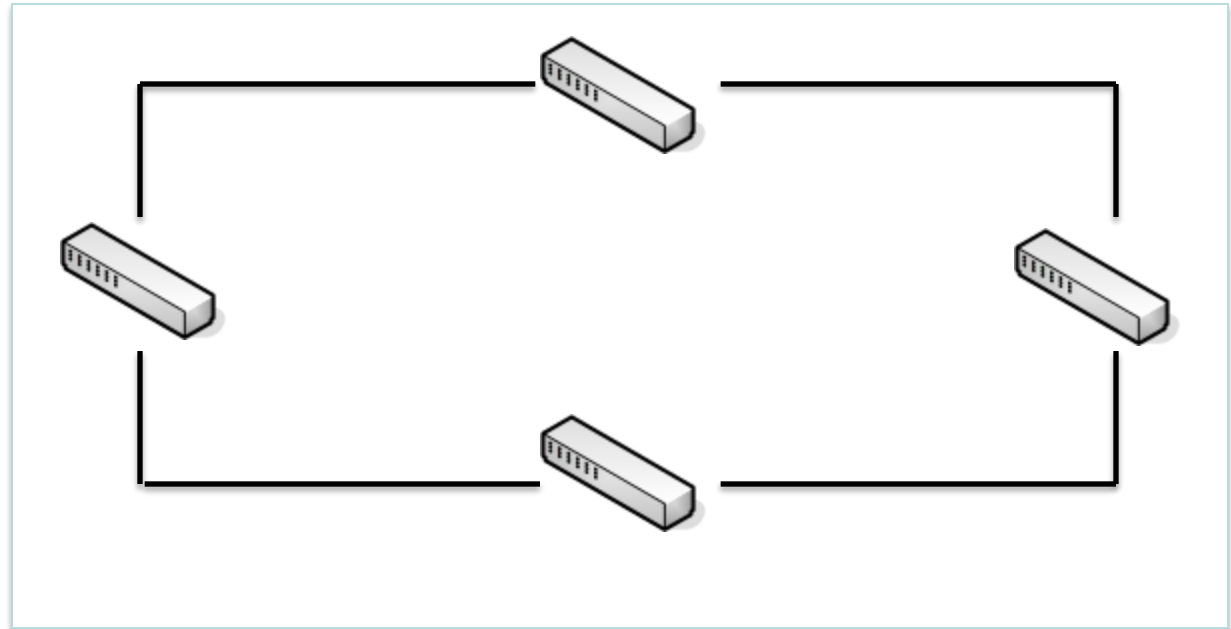


## RSTP = Rapid Spanning Tree Protocol

- ❑ Most established, most popular, widely used
- ❑ Supports any topology (ring, mesh, star etc)
- ❑ Self-healing, quick-recovery time, (5ms per hop)

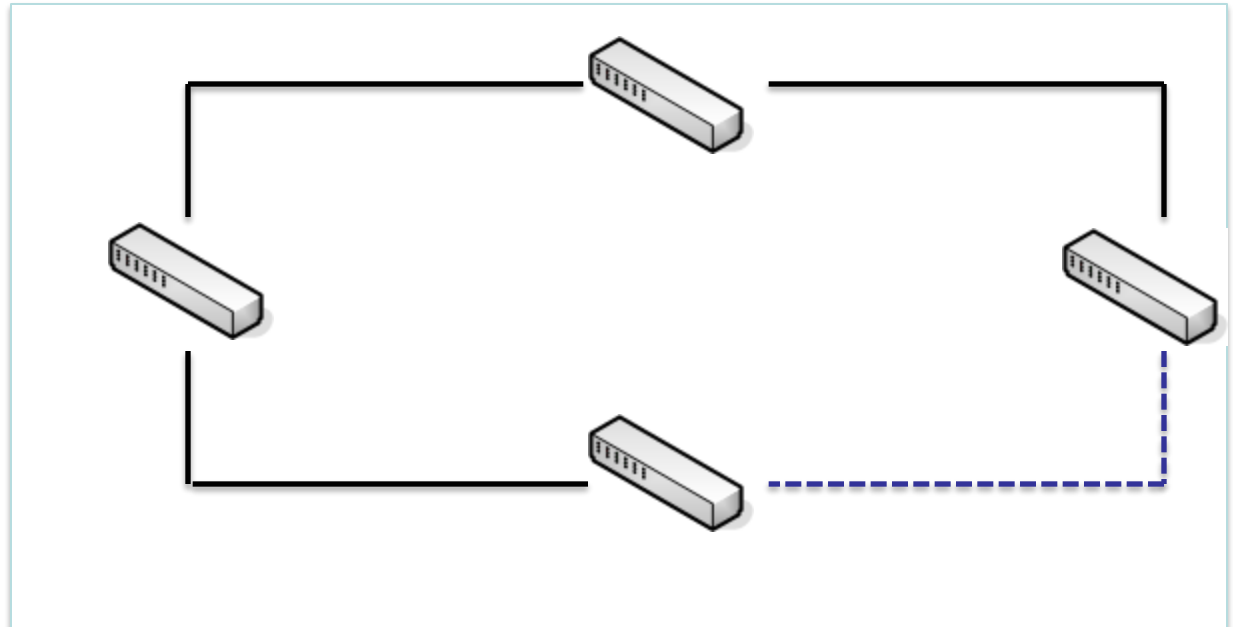
## RSTP = Rapid Spanning Tree Protocol

RSTP Ring architecture



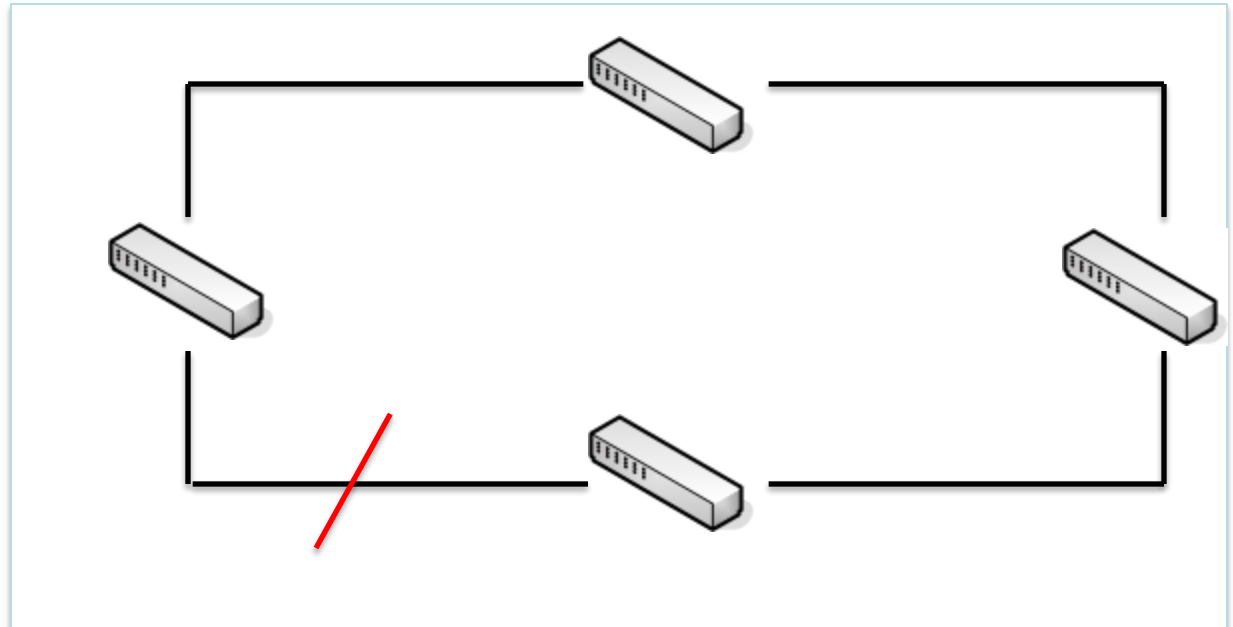
## RSTP = Rapid Spanning Tree Protocol

- Switches decide which links are redundant and removes them to prevent network loops
- Physical links remain



## RSTP = Rapid Spanning Tree Protocol

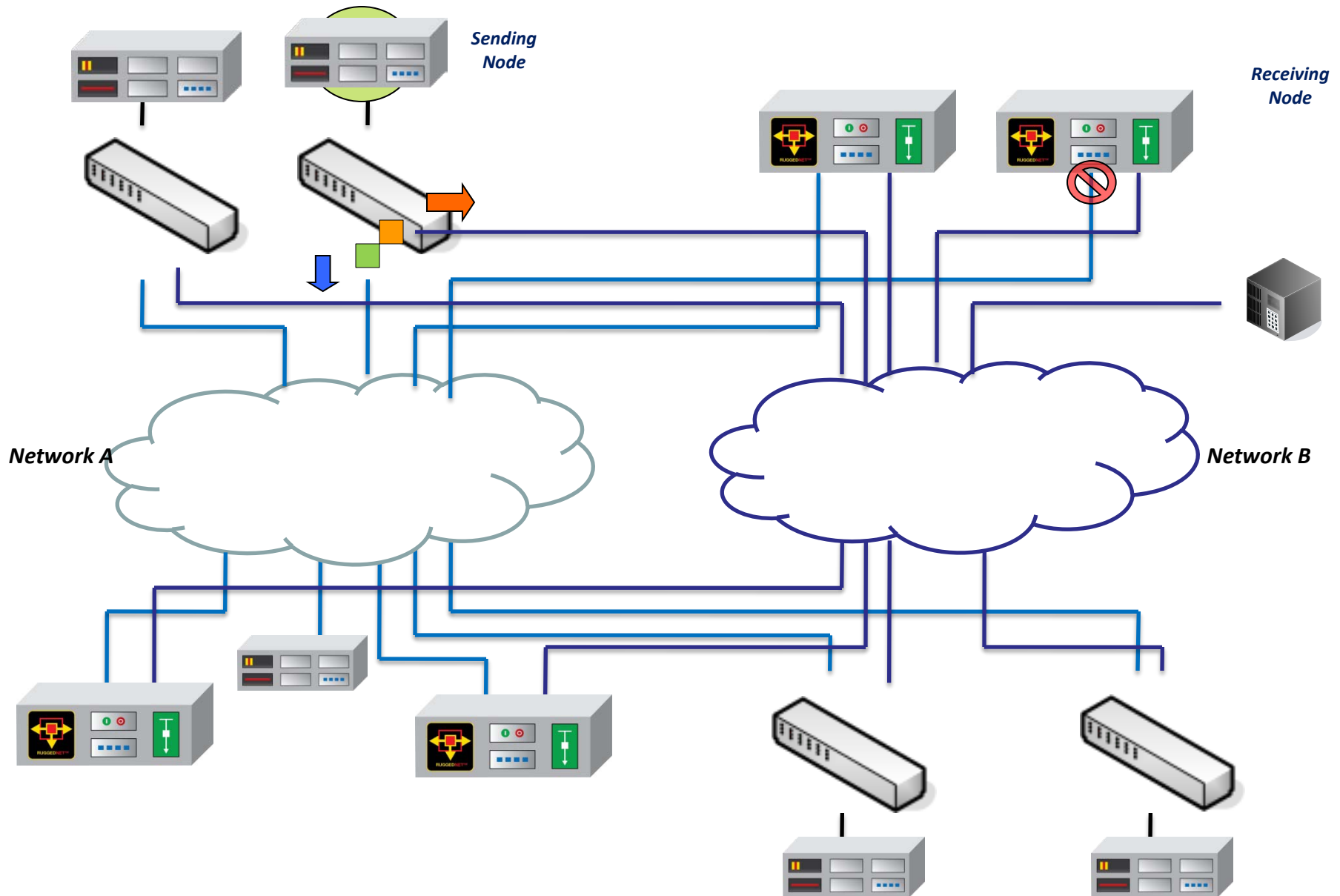
- If a fault occurs  
RSTP restores the  
link



## **PRP = Parallel Redundancy Protocol**

- Guaranteed 'ZPL' (Zero Packet Loss) for any single point of failure
- Zero recovery time
- Supports any topology (ring, mesh, star etc)
- Chosen by IEC 61850 for mission critical substation networks
- Essential for future 'process bus' networks
- Future IEDs may include HSR and / or PRP built in

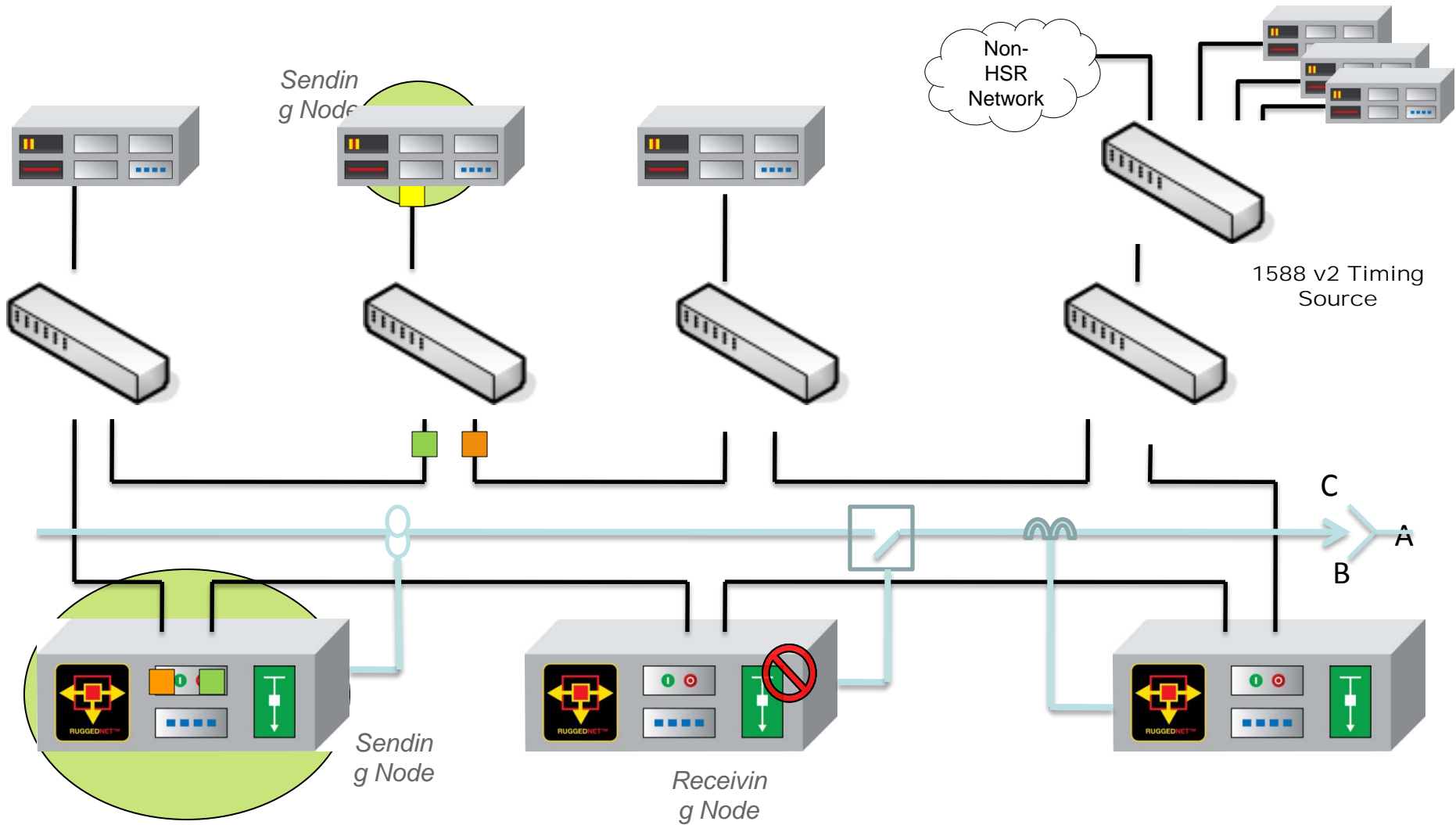
# IEC 62439 PRP Quick Overview



## HSR = High Availability Seamless Ring

- ❑ Built on concept of PRP – (Dr. Hubert Kirmann)
- ❑ It is a peer-to-peer network
- ❑ Bandwidth is effectively halved, but so is cost
- ❑ Guaranteed ‘ZPL’ (Zero Packet Loss) for any single point of failure, essential for ‘process bus’ networks
- ❑ Ring topology and interconnected rings
- ❑ Chosen by IEC 61850 for mission critical substation networks
- ❑ RedBox connects legacy Ethernet IEDs to HSR ring
- ❑ QuadBox interconnects rings
- ❑ Future IEDs may include HSR built in

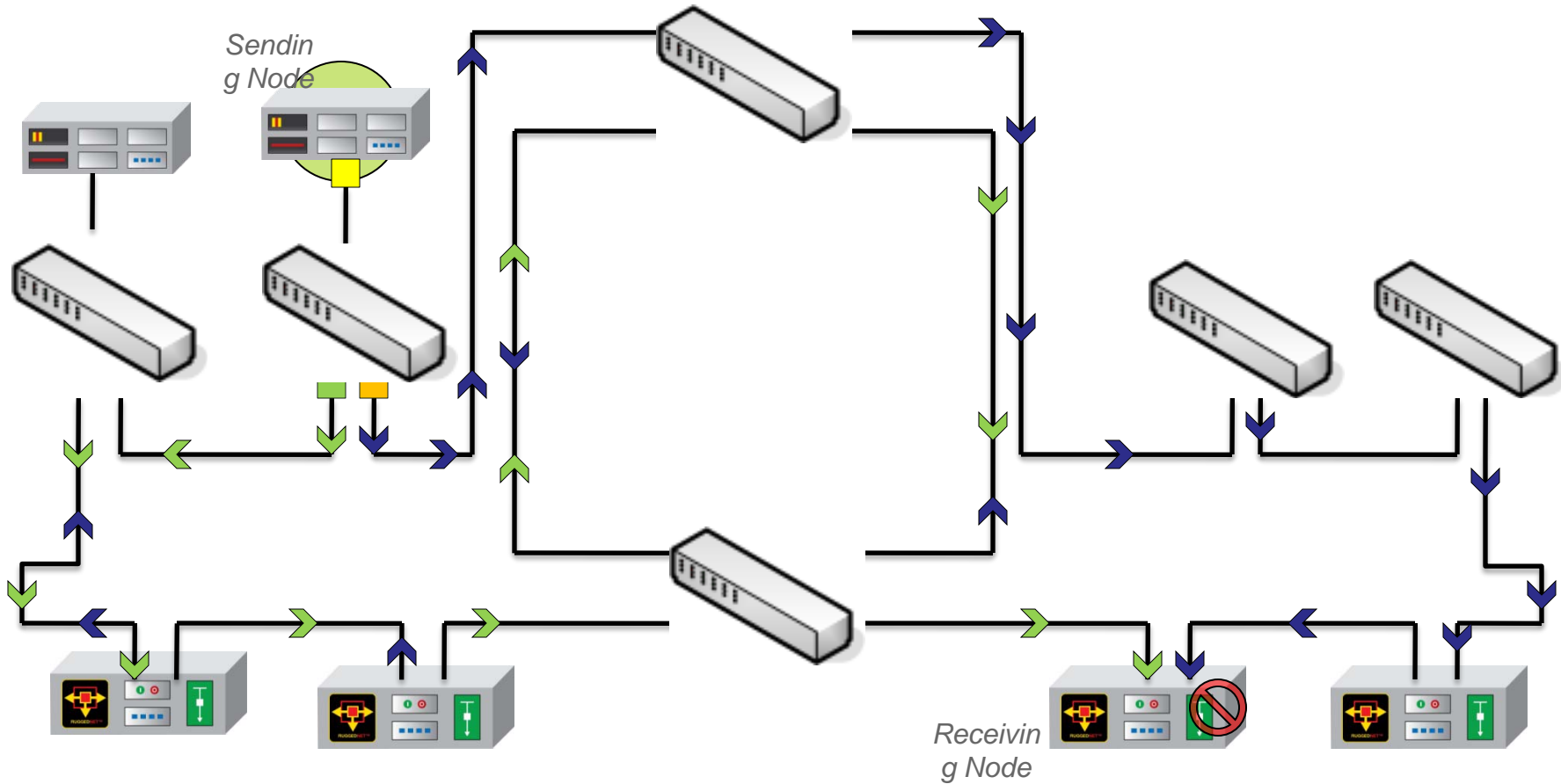
# IEC 62439 HSR Quick Overview





# IEC 62439 HSR Quick Overview

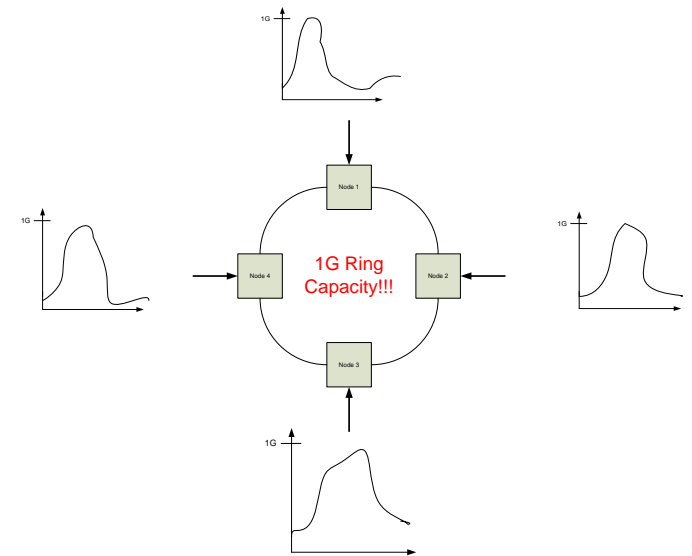
HSR – Scaling up, linking rings with a Quad-box



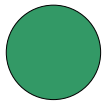
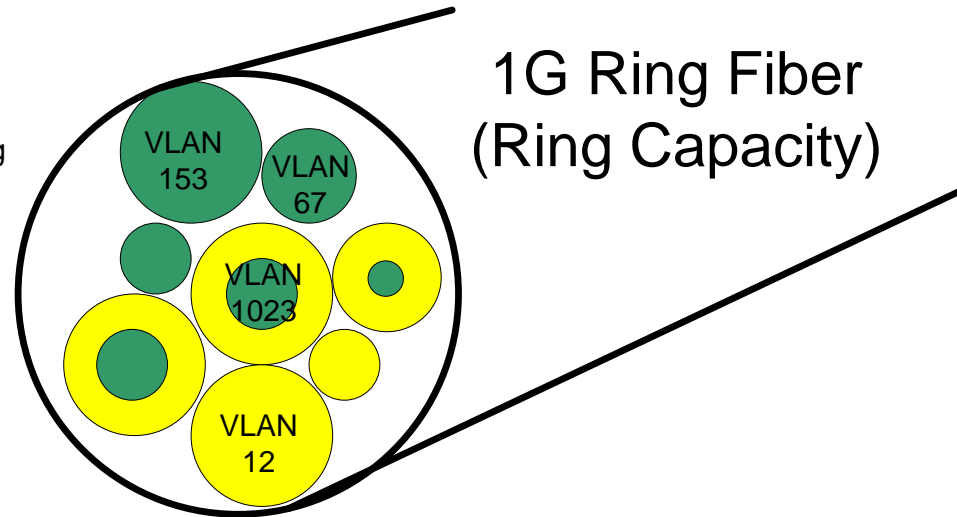
## 'Seamless' Failover Does Not Guarantee Delivery

- ❑ GOOSE traffic from multiple IEDs is quasi synchronized
  - IEDs all see and react to power system events at same time
- ❑ 9-2 traffic is synchronized via IEEE 1588
  - Merging units send traffic at exact same instant in time
- ❑ “Instantaneous bandwidth” is greater than bandwidth of network
  - Phenomenon same for HSR and 802.3
- ❑ Up to 4G Traffic Injection in short term
- ❑ 1G Ring Capacity!!!

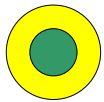
⇒ **Even Short term congestion can result in dropped packets**



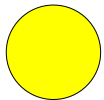
**VLAN Tunelling:** VLANs define tunnels around the ring



**Guaranteed Bandwidth:** Guaranteed Bandwidth around the ring. **The bandwidth is always available.** If not used it can be reused by other lower traffic class.  
 - No packet drop.  
 - Low delay and jitter (if bandwidth is reused by lower traffic class, current packet is aborted and re transmitted later)



**CIR/PIR Bandwidth:** Mix of guarantee and shared bandwidth around the ring. A portion of the bandwidth is guaranteed and another portion of the bandwidth is shared among other traffic class. The CIR (green) portion is always available and the PIR (yellow) portion may or may not be available. If the CIR portion is not used it can be reused by other lower traffic class.  
 - Packet drop will occur (service must tolerate packet drop, all TCP applications are packet drop tolerant).  
 - Higher delay and jitter (if bandwidth is reused by lower traffic class, current packet is aborted and re transmitted later)



**Best Effort Bandwidth:** Shared Bandwidth around the ring. No Guaranty  
 - Starvation may occur.  
 - Unbound delay and jitter

## 1588 Features for HSR and PRP:

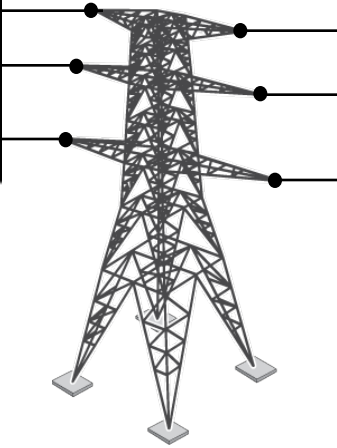
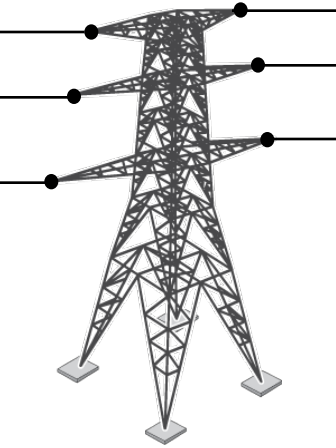
- Support real time Ingress and Egress time stamping
- Support 1-Step Peer to Peer Delay measurement with node awareness
- Packet correction field accounts for switch processing time and propagation delay
- Port AWARENESS!

## HSR Interoperability Considerations

HSR has no intermediary network switch, it is a peer to peer network architecture requiring interoperability between IED vendors.

- ✓ IEC 62439 Standard
- ✓ Supports compatible QoS / CoS (not defined in 62439)
- ✓ Compatible IEEE 1588v2 profile (not defined in 62439)

	RSTP	PRP	HSR
Standard	Well known and accepted	Standard	New standard
Impact on End Nodes	None	Dual Attached Interface	Dual Attached Interface
“Seamless” failover	No	Yes	Yes
Reduced Loss Rate	No	Yes	Yes
Cost	Mid	Double Infrastructure + DANs	DANs but less switches
Bandwidth	No Impact	No Impact	Half
Application Independent	Yes	Yes	Yes



**Thank You!**