Network Resiliency

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

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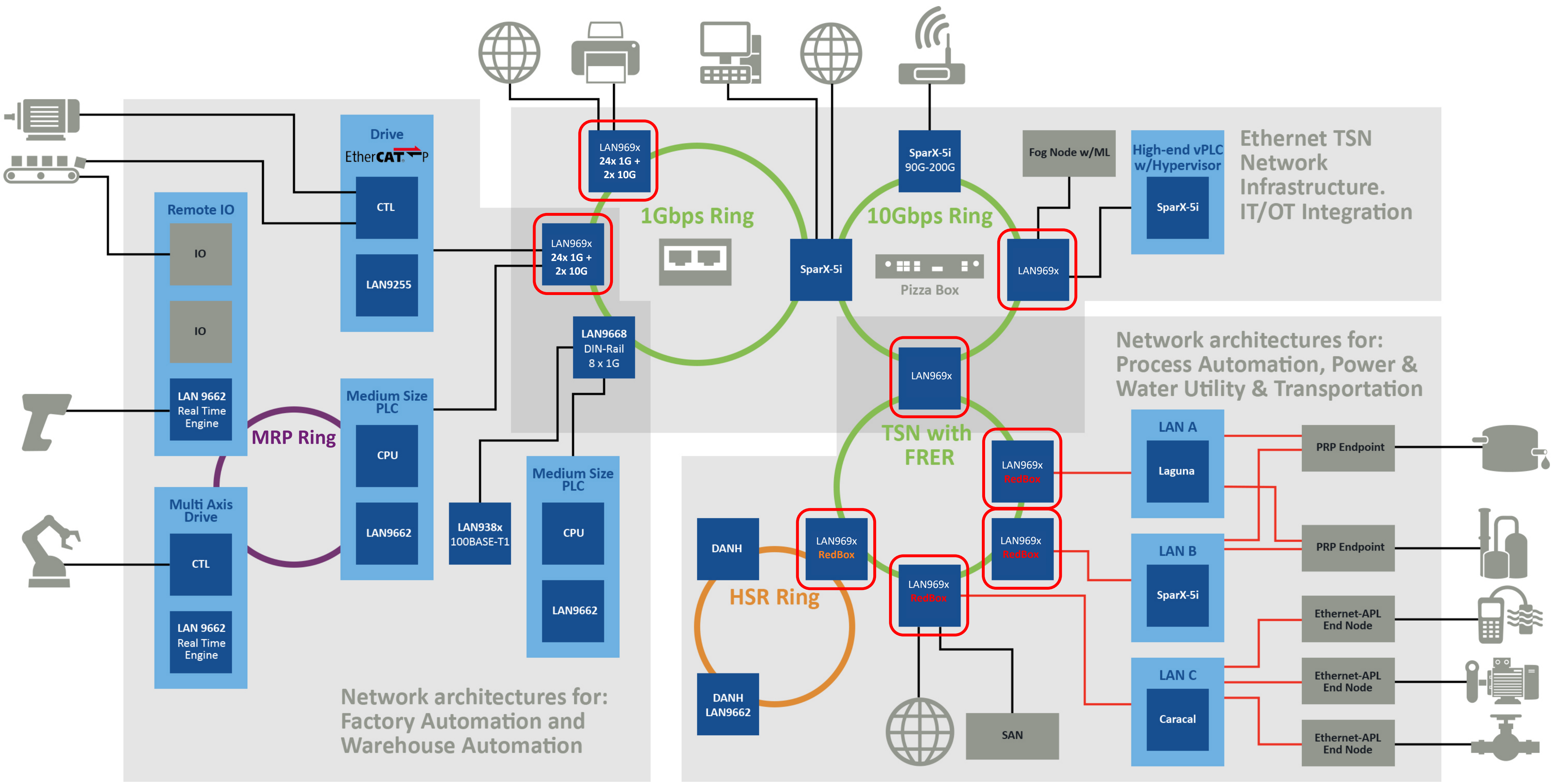
Agenda

- **Example of Interconnected Networks**
- **Switch Types**
  - Unmanaged
  - Managed
- **Resiliency Standards**
  - Spanning Tree Protocol (STP)
  - Media Redundancy Protocol (MRP)
  - Frame Replication and Elimination for Reliability (FRER)
  - High-availability Seamless Redundancy (HSR)
  - Parallel Redundancy Protocol (PRP)
- **Reference Designs**

Example Interconnected Network



Key Considerations For Network Resilience

- Resilience provides the ability to recover from a cable / device / network interface failure
- Many different protocols are defined for specific uses (telecommunications, grid automation, ADAS)
- Some may provide seamless failover (no loss) or will recover in a given time period
- Some applications cannot tolerate packet loss
- Some protocols support carrying PTP, others may not
- Some will allow interconnected rings of the same type
- It may be necessary to interconnect between different redundancy protocols (Bridge/Redbox)
- Standardised to allow interconnection between different vendors equipment

Switch Types

- **Unmanaged**
  - Pretty much turnkey
  - No or very little software overhead. Functionality inherent in switch SoC
  - No redundancy

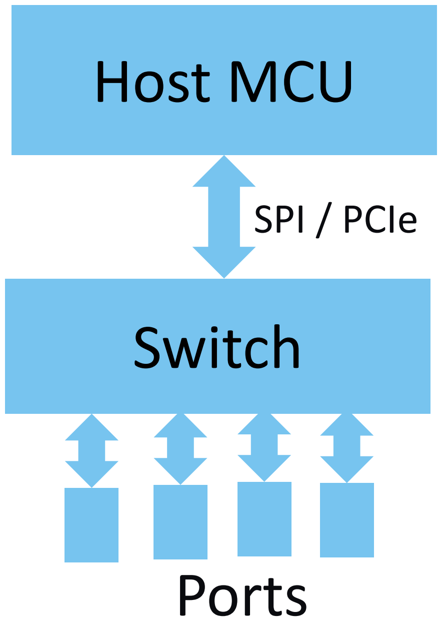
- **Lightly managed**
  - More functionality – VLAN support typically, STP/RSTP support
  - Could be bare metal or Linux / Switchdev or other OS. GUI required?
  - An amount of port-based security - VLAN
  - GUI and SNMP potentially for monitoring / configuration
  - Medium cost of implementation / time to market dependent on complexity

Switch Types

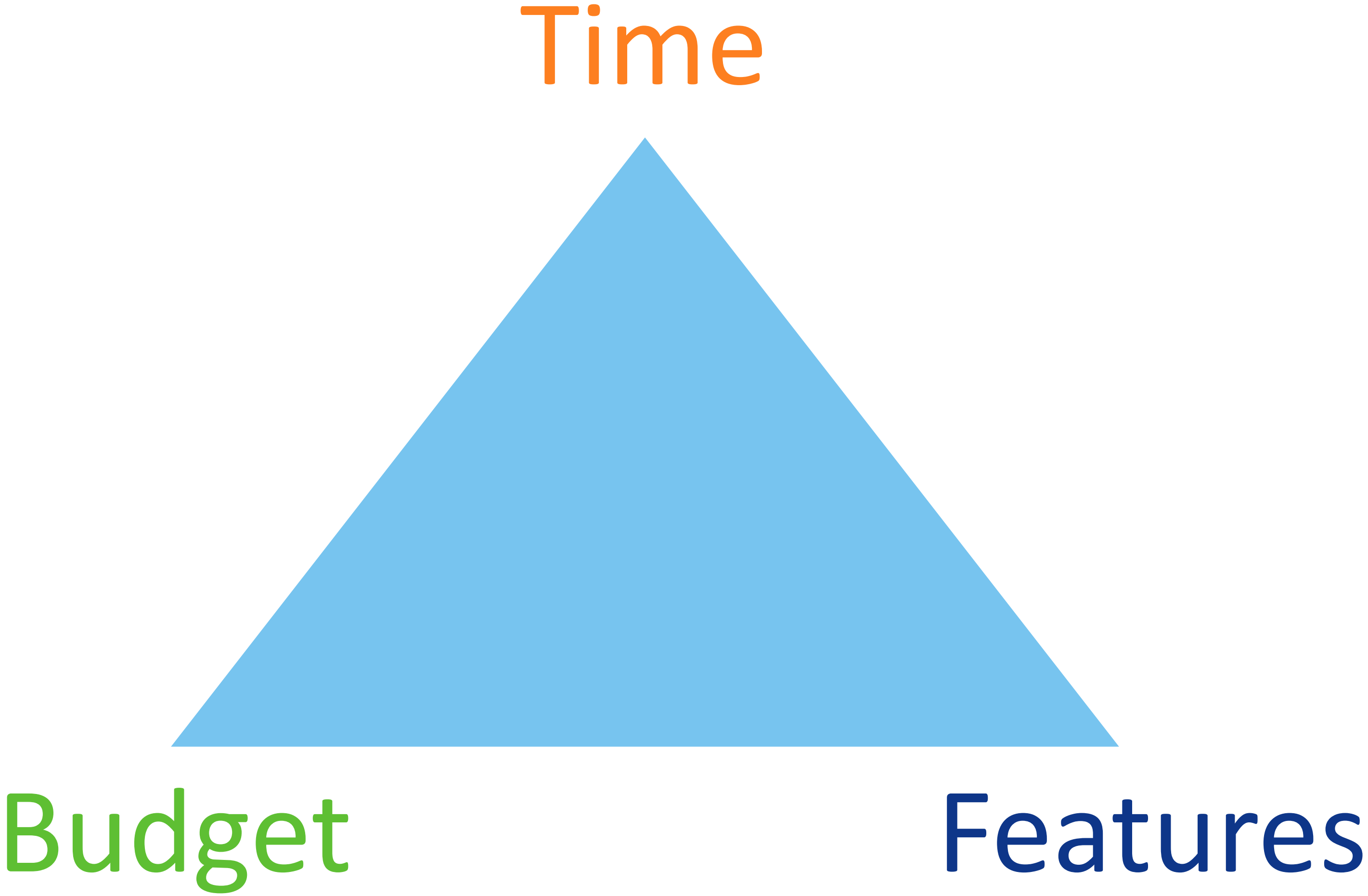
- **Fully managed**
  - Comprehensive protocol support; PTP, time-based traffic shaping, VLAN, QoS, prioritization, pre-emption, link aggregation as well as redundancy such as MRP and FRER
  - Linux or other OS based. Switchdev plus Linux patches or turnkey OS for higher function devices
  - Performance balance between on-chip peripherals and host MCU. Protocol offload ability
  - Support for multiple management protocols
  - GUI and SNMP potentially for monitoring / configuration. Switch management plane. CLI - Field configurability? CLI documentation, product GUI branding?
  - Higher cost of implementation / longer time to market. Hardware / layout likely to be faster to develop than software

Managed Switch Architecture

- **Provide Layer 2 (MAC) and often Layer 3 (IP) functionality**
- **Will have a host MCU/CPU to configure the switch**
- **Frame processing done by switch rather than host**
- **The interface between the switch and host can depend on the design – SPI and PCIe typically used**
- **Host may be running an OS or bare metal**
- **Host may be internal to switch or external**
- **Lightly managed or fully managed?**
  - What feature set do I need?
  - Does a user need to configure the switch?
  - Does the switch need to a GUI or CLI?
  - Is the switch an embedded design?



Key Design Criteria



Resilience Standards and Examples

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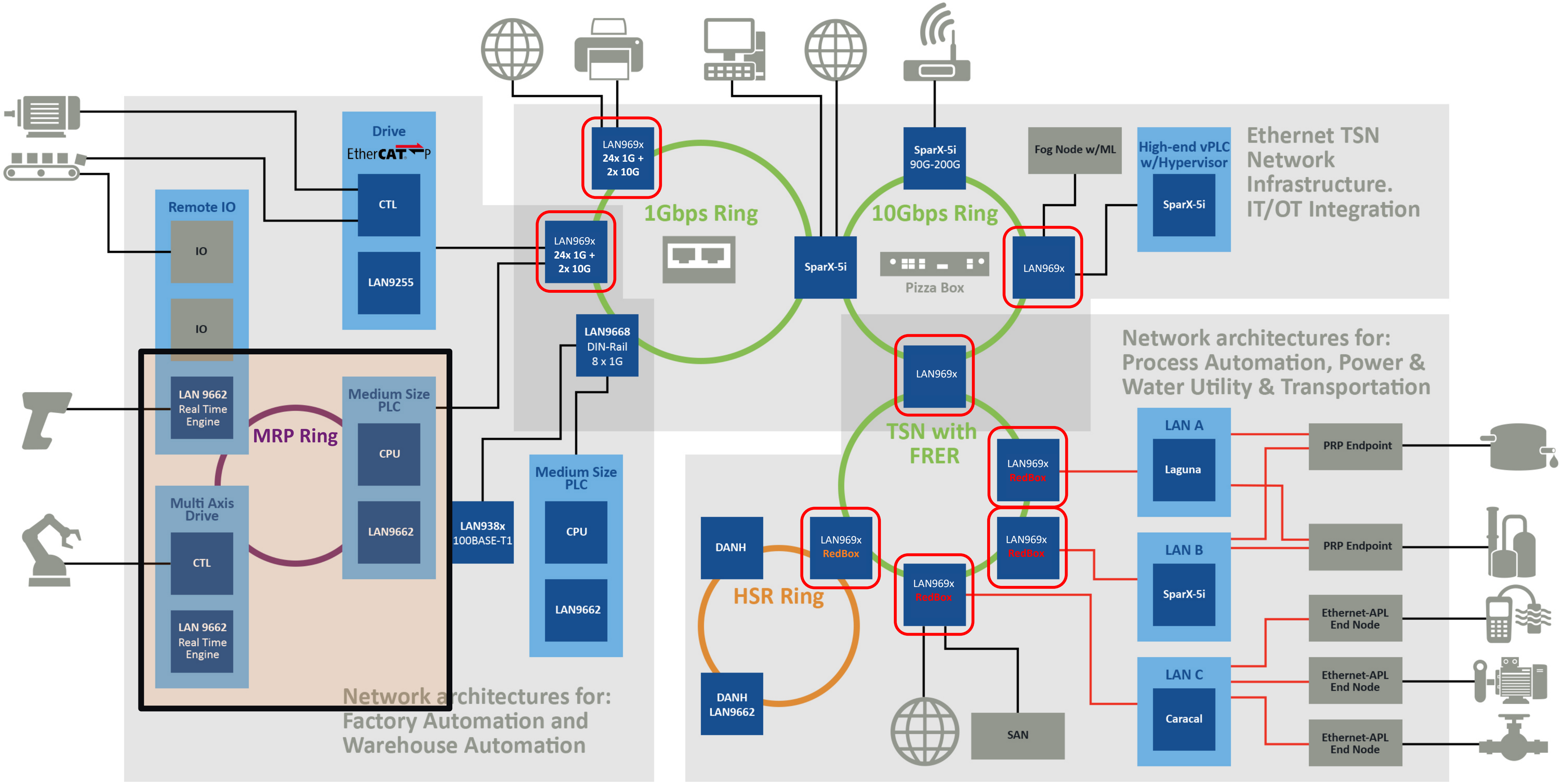
Typical Redundancy Standards

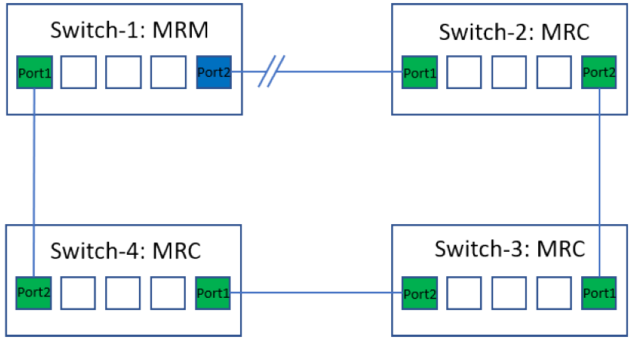
- **Spanning Tree Protocol - STP / RSTP**
  - Very common in IT applications. Acts to keep network loops from occurring
  - Slow to recover from network fault / regain link
  - Will require STP/RSTP stack to implement
- **Media Redundancy Protocol - MRP**
  - Can provide nested rings and fast recovery time although implementation dependent. Mandated in Profinet
- **FRER**
  - Unidirectional stream based protocol, zero loss, supports distribution of time
- **HSR/PRP**
  - HSR is a ring topology, PRP exists over separate, parallel networks. Zero packet loss recovery, supports distribution of time. Used in grid automation systems typically
- **DLR**
  - Ring topology, used with Ethernet/IP protocol. One network interface blocked until fault and then opened
- **G8032 ERPS**
  - Ring topology or nested rings, used in telecoms applications

TSN Network Example: MRP



IEC Media Redundancy Protocol (MRP)

- **MRP is a recovery protocol based on a ring topology**
- **It is designed to react deterministically on a single failure of an inter-switch link or switch in the network, under the control of a dedicated Media Redundancy Manager (MRM) node**
- **Unlike another well-known ring protection protocol like ERPS, MRP blocks or unblocks the entire ring port rather than only a set of VLAN IDs**
- **MRP is defined by International Electrotechnical Commission (IEC)**
  - IEC 62439-2 standard, edition 2.0, 2016-03
- **IEC MRP is not to be confused with IEEE's Multiple Registration Protocol**
- **Mandated in Profinet**



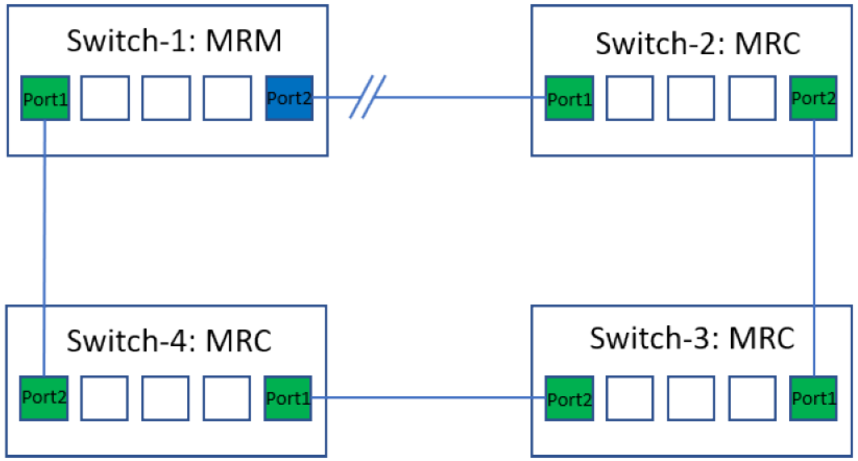
IEC Media Redundancy Protocol: Performance

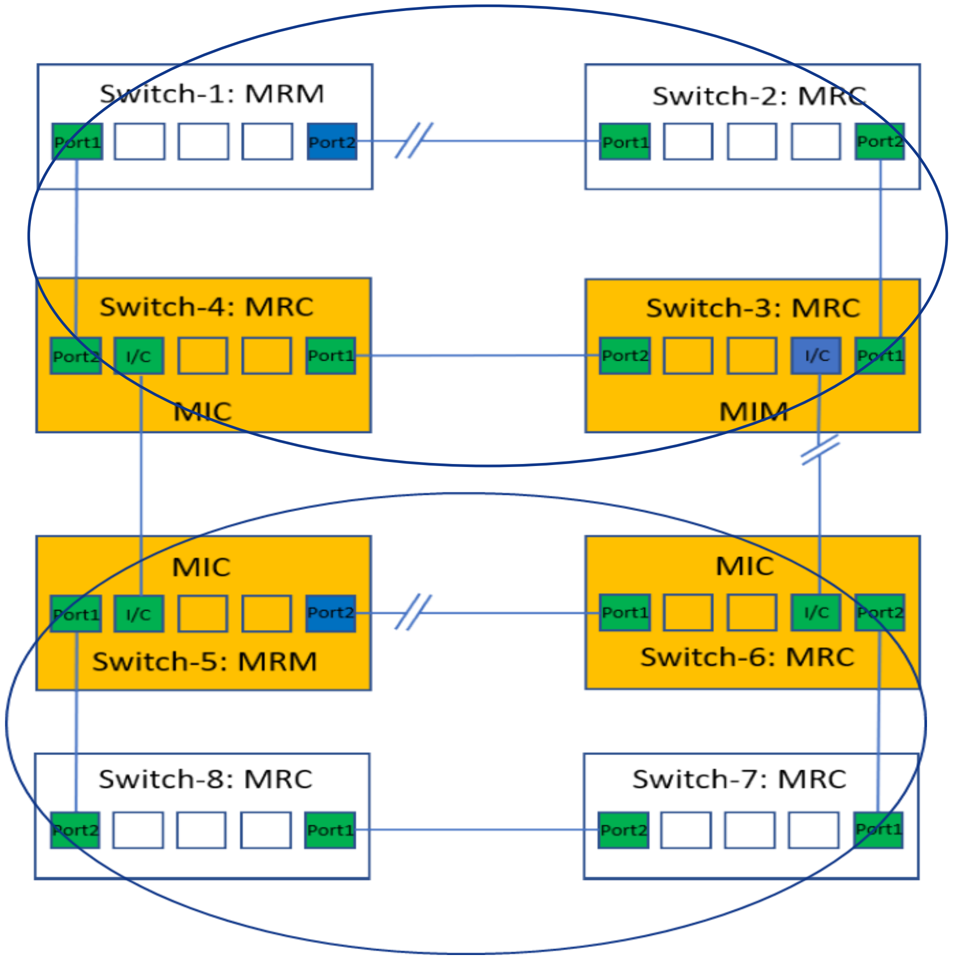
- **The MRP protocol can be CPU consuming as more than 2000 PDUs per second may have to be transmitted, received and processed by each node in a single MRP ring. Also, the ring interconnects with another ring**
- **Each node can handle between 1 and N separate rings at a time**
- **The upper limit is defined by the actual switch chip and its hardware capabilities. The more hardware offload features the switch chip supports, the more ring instances can be created simultaneously**
- **Some switch chips do not have any hardware offload and are limited to creating only one single ring instance, since everything is handled by software. i.e. Ocelot/VSC7514**
- **Other chips have hardware support for automatic frame transmission and can support a few more ring instances. i.e. SparX-5i/VSC755x**
- **Others have support for both automatic frame transmission and reception, so the burden on the CPU is minimal. These chips have support for up to X/2 rings, where X is the number of ports on the platform on which the chip resides. i.e. Maserati/LAN9668**

MRP Capabilities	Ocelot-1 / VSC7514	SparX-5i / VSC755x	Maserati / LAN9668
Max. Instance count:	1	2	4 (port limited – X/2)
Fastest recovery profile:	200 ms	200 ms	10 ms
H/W transmits MRP_Test/MRP_InTest PDUs:	No (AFI cannot be used)	Yes	Yes

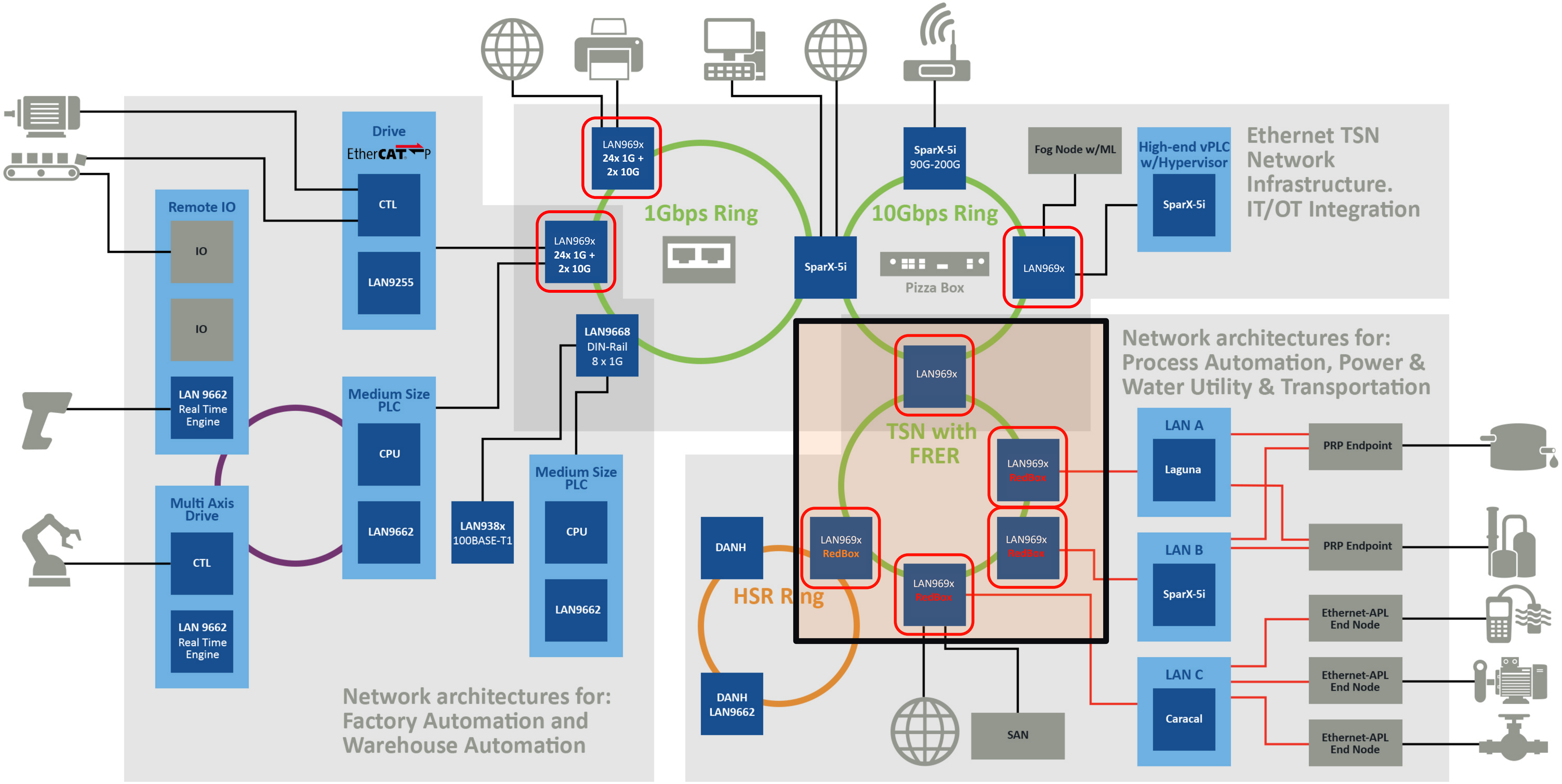
Media Redundancy Protocol IEC 62439-2

- **The Microchip HW Engine supports the following roles:**
  - Media Redundancy Manager (MRM)
  - Media Redundancy Client (MRC)
  - Media Redundancy Auto-Manager(MRA)
  - Media Redundancy Interconnection Manager (MIM)
  - Media Redundancy Interconnection Client (MIC)
  - 10ms recovery time with MCHP
- https://github.com/microchip-ung/mrp





TSN Network Example: FRER

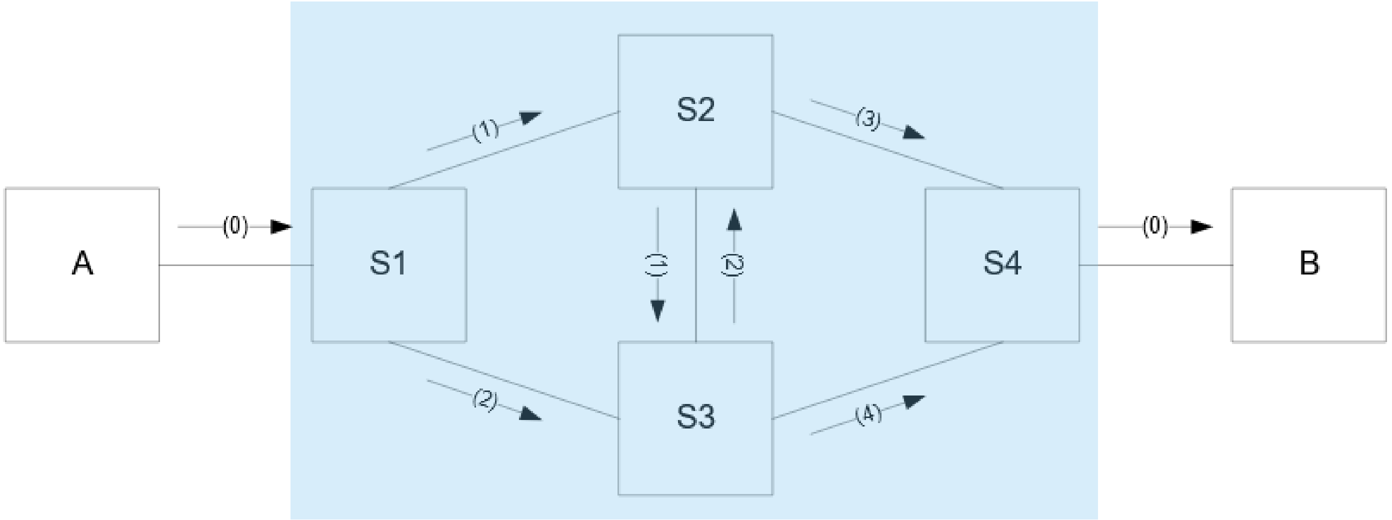


Frame Replication and Elimination for Reliability (FRER) - IEEE 802.1CB-2017

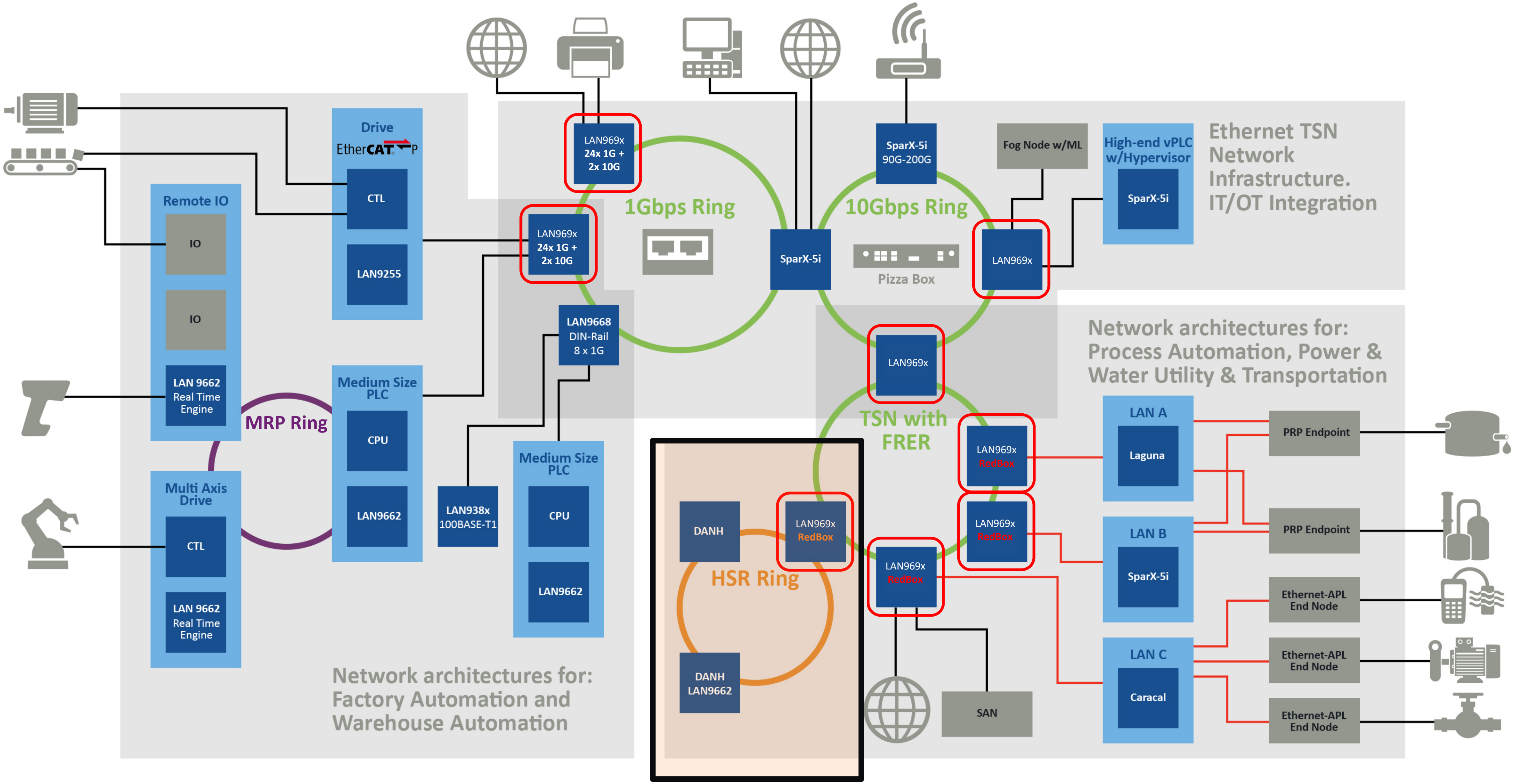
- FRER reduces the probability of packet loss by replicating packets at the source, transmits these replicas over multiple paths and finally removes duplicate packets at the destination
- Allows meshing of networks
- Supports and maintains TSN networks and provides zero recovery time
- FRER requires dedicated switch hardware to implement
- Frames are transported and processed using VLANs and priorities are allocated by streams (talkers and listeners) to limit network congestion
- FRER is not currently implemented in mainline Linux, as such Microchip provide a dedicated tool – 'frer'

FERR Continued

- **FRER requires all participants to be FRER aware**
- **FRER networks comprise of:**
  - End System (ES) – Contain talkers and listeners; may be end points such as cameras, sensors, drives and actuators (A and B in diagram)
  - Relay System (RS) – Act as gateways between End Systems and the redundant network S1 - S4 in diagram
  - S1 and S4 are also known as “Red boxes” which link between redundant and non-redundant networks



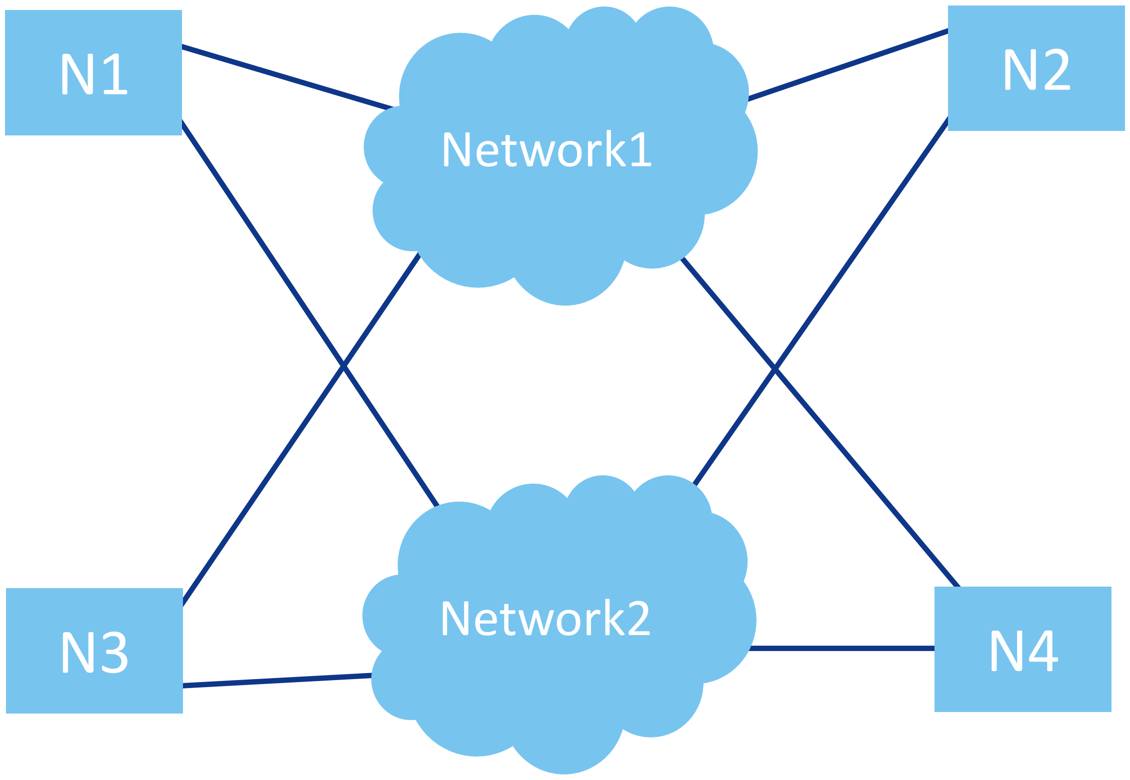
TSN Network Example - HSR



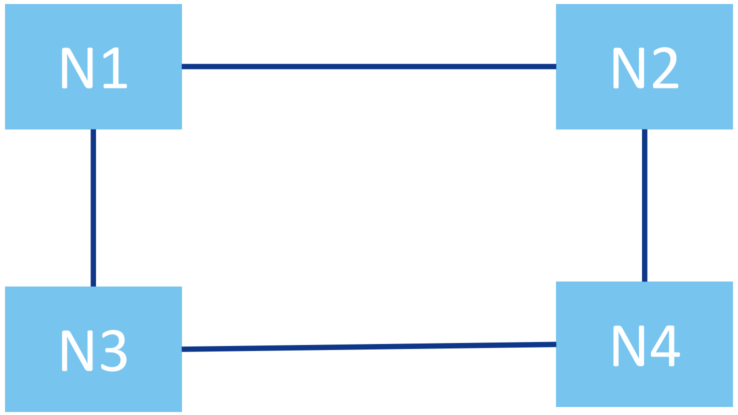
HSR and PRP

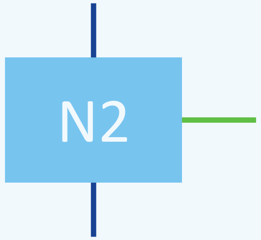
HSR and PRP Operate using “Red Boxes” – Redundancy Boxes

- **PRP Network**



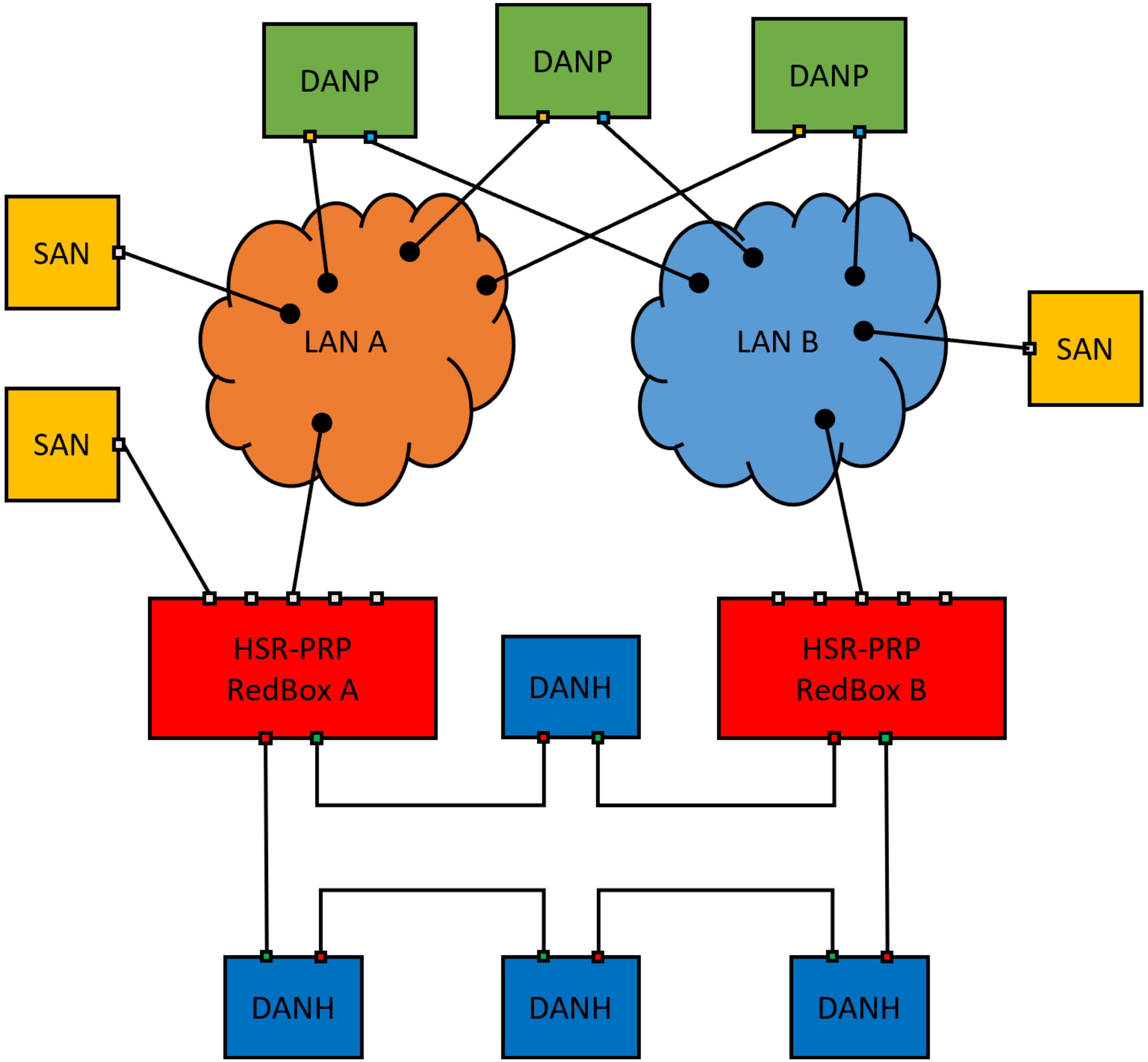
- **HSR Network**





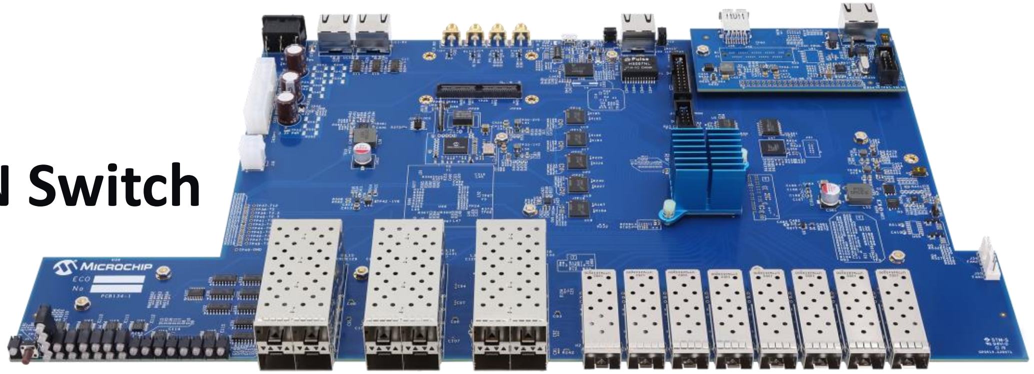
Red box contains two parallel connections to network plus internal (green)

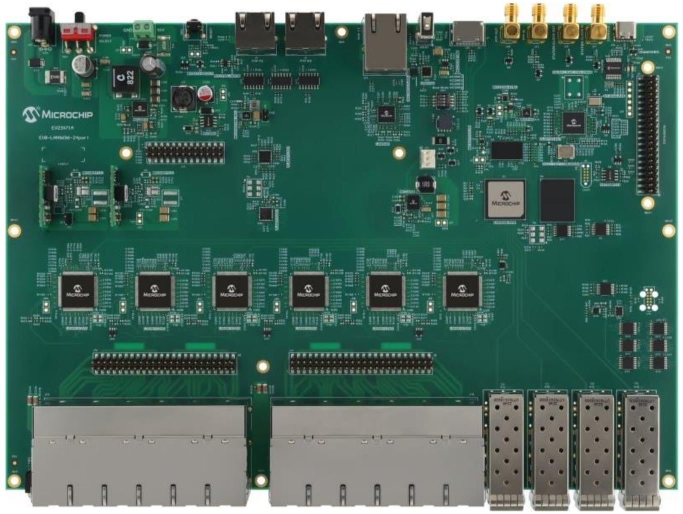
TSN Network Example: HSR/PRP



Reference Designs

VSC7558 “SparX-5i” 10 / 25 Gbit TSN Switch





LAN969X “Laguna” 10 Gbit TSN Switch

LAN9668 “Maserati” 1 Gbit TSN Switch

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Summary

- This presentation provided an overview of key resilient network topologies, highlighting their core concepts, benefits, and limitations:
- Diverse Protocols: Many network redundancy protocols exist, often tailored for specific applications but adaptable to other use cases as needed.
- Topology Choices: Ring topologies enable recovery from single failures, while meshed networks offer higher redundancy and protection against multiple failures.
- Failover and Bandwidth: Some protocols offer seamless, lossless failover; others recover within a set time but may duplicate frames, reducing bandwidth efficiency.
- PTP Support: Not all protocols support Precision Time Protocol (PTP); this must be considered for time-sensitive applications.
- Switch Types: Lightly managed switches typically support basic protocols like STP/RSTP, while fully managed switches handle advanced redundancy schemes and bridging.
- Hardware Requirements: Dedicated hardware in the switch SoC enhances performance, reduces CPU load, and is essential for many redundancy protocols.
- Standardization: Adhering to standards ensures interoperability between devices from different vendors.
- In summary, resilient network design involves selecting appropriate protocols and hardware based on application needs, balancing redundancy, performance, and interoperability.

Thank You!

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