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Seamless Merging of PRP and HSR Networks without External RedBoxes

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ABSTRACT The Industry is converging on Ethernet. During latest year, some technology innovations have emerged to enhance the resilience of standard Ethernet network and to use it as a common link layer for Operation and Information technologies. Critical sectors, like the Electric one, with high-availability and strict timing requirement have pushed these developments.
The next step forward to allow diverse applications taking benefit from this innovation is providing to system integrators ready-to-use equipment. In this sense, this paper presents a use-case of a Smart PCIe card model, **RELY–**SYNC-HSR/PRP-PCIe , from **RELY–**PCIe product family. This solution supports zero-delay recovery time Ethernet protocols (HSR and PRP) and manages Precise-Time-Protocol (PTP or IEEE 1588) autonomously for accurate time synchronization over Ethernet. Additionally the board integrates the clock protocol gateway, simplifying the synchronization of legacy systems not compatible with the PTP reference.
As an example, the use-case presented solves a demand of integrators of High-Availability Ethernet networks: A simple interconnection of PRP and HSR Networks. This solution removes the need for additional intermediate RedBox external equipment integration and allows reusing the existing Gateways or PC Scada Systems to manage the packet processing thanks to the dual functionality of DAN and RedBox embedded on **RELY–**SYNC-HSR/PRP-PCIe .

KEYWORDS
PTP
NTP
HSR/PRP
SCADA
PCIe

INTRODUCTION

Ethernet

Most of these Industrial Networks are Ethernet-based. Since Ethernet was standardized in 1983, it has evolved both from the technical and from the application point-of-view as well. The original use for computer networks has been extended to be the de-facto Data Link protocol for field-buses in Industry (Profinet, Ethernet IP, Ethercat, Sercos III, etc.), Aerospace (AFDX), Energy (IEC 61850), Automotive (Deterministic Ethernet) and Transportation.

Critical systems like Substation Protection, Automa-

tion and Control System (PACS) can benefit from Ethernet technology if it ensures no-frame lost in case of a network failure, effective integration of accurate timing synchronization schemes, inter-operability among vendors and some basic real-time operative capabilities.

In this sense, a very valuable standardization effort has been carried out at IEC organization releasing IEC 62349-3 'Industrial communication networks - High availability automation networks´ (3). In coordination with this work, a specific profile of the Precise Time Protocol -IEEE 1588- able to run in these redundant environments has been developed and released (1).

High-availability Ethernet

Parts 5 and 4 of this standard IEC 62349-3 define High-availability Seamless Redundancy (HSR) protocol and Parallel-Redundancy-Protocol (PRP) respectively. Both offer zero-delay recovery time and no-frame lost over Ethernet Networks. HSR is oriented to Ethernet ring topologies and it ensures a known worst case scenario for frames delivery time. PRP works with two independent legacy Ethernet Networks and it is not intended to work within real-time scenarios. Indeed, PRP, HSR and PTP can be combined to support time-aware networks.

Precise Time Protocol (PTP)

Sub-microsecond synchronization is more and more demanded in Industrial Control Systems. As an example of the introduction of this combined approach in the Industry (Reliable Ethernet combined with IEEE 1588), the IEC Smart Grid Strategy Group recommends PTP, as defined in IEEE 1588-2008 standard (5), for high precision time synchronization in substations.

PTP distributes absolute time across a substation network directly over Ethernet, achieving synchronization accuracies in the range of nanoseconds. PTP systems follow a master-slave hierarchy, where the master imposes the time and the slaves synchronize to it in both phase and frequency (8). The propagation delay is automatically compensated by slaves and, in order to consider latencies introduced by network nodes, Transparent Clock (TC) functionality must be added in intermediate nodes.

Therefore, all switches in the network shall support TC operation to correct the PTP frames that are switched in order not to lose the expected accuracy. The typical PTP network is completed with PTP Boundary Clock devices that separate different clock regions and with PTP Ordinary Clocks that are capable of working as Master and Slave devices.

Apart from this widely use in the Electric sector, IEEE 1588 is more commonly found in other scenarios. As an example, some of the targeted applications are distributed sensor data acquisition for Gas&Oil (2), time reference for Deterministic Ethernet (9; 4), phase and frequency synchronization for motor drives (7) or distributed data acquisition from DAUs in Aerospace&Defence (6).

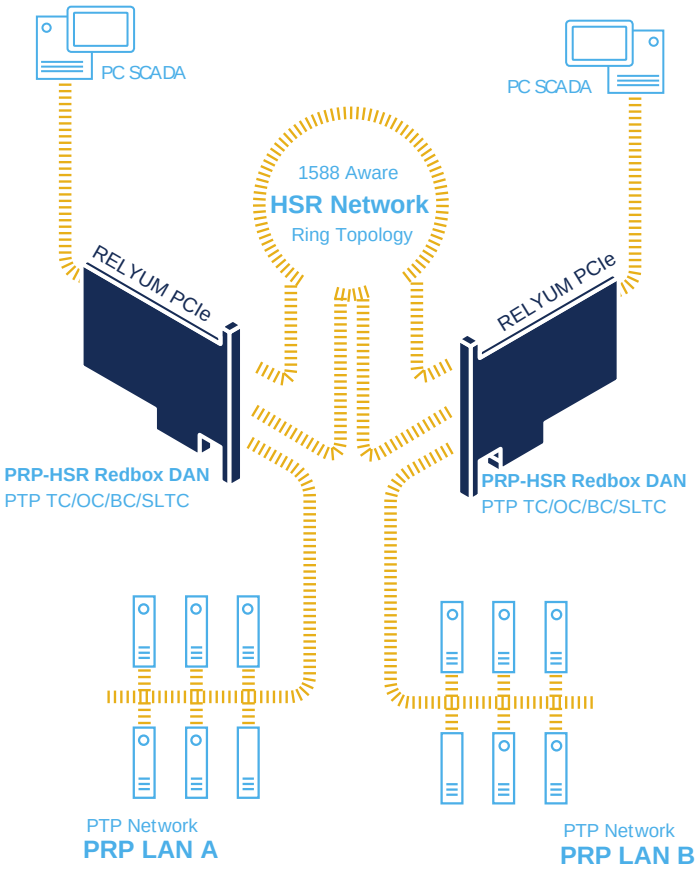

Figure 1 Merging PRP and HSR networks using **RELY**–SYNC-HSR/PRP-PCIe solution

USE-CASE: SEAMLESS MERGING OF PRP AND HSR NETWORKS

Critical infrastructures that require fully redundant paths in real-time sections and in non-real time ones can benefit from combining PRP and HSR networks. PRP is composed by two standard Ethernet networks, and the PRP capable equipment is in charge of sending and receiving duplicate frames through both LAN networks. This approach is very adequate to reuse regular Ethernet infrastructure, but it lacks from any mechanism to ensure the worst case delivery time for a given frame. HSR allows calculating this parameter. Therefore it is an standardized and inter-operable solution

suitable for control oriented communications. As an example, the typical zero-delay recovery time topology for IEC 61850 substations is based on implementing PRP in the Station bus section and HSR rings for the Process bus areas. The connection of a PRP network with an HSR ring must be done through two different points, avoiding the previously mentioned SPOF. The IEC 62349-3 standard defines how shall be the behaviour of the equipment that is doing the interconnection. Specifically, they need to support the PRP-HSR mode to manage correctly the sequence number field when the frames pass through one network to the other. From the integrator point of view, one option is combining and configuring PRP-HSR capable standalone RedBox equipment with support for an IEEE 1588 profile able to deal with (combined) redundancy.

Figure 2 RELYUM at CFAA center

Another alternative, implemented in the Aeronautics Advanced Manufacturing Center plant (CFAA , Figure 2), consists of using two **RELY**–SYNC-HSR/PRP-PCIe cards plugged in two industrial PC computers like the one shown in Figure 3. This set-up allows interconnecting the PRP section with the HSR one in the plant thanks to the PRP-to-HSR special mode supported by these devices. Figure 1 summarizes the set-up diagram. For this setup, the HSR rings are fiber optic , while the PRP network is a GbE copper media. Each PRP branch is connected to the Ethernet input that regularly is used to attach the standard LAN in a RedBox operation. The configuration is done in few minutes and only once: the operator connects to the Web application embedded in the PCIe card and selects PRP-HSR operation as shown in Figure 4. That is all!

Figure 3 **RELY**–SYNC-HSR/PRP-PCIe card plugged on the PC Server.

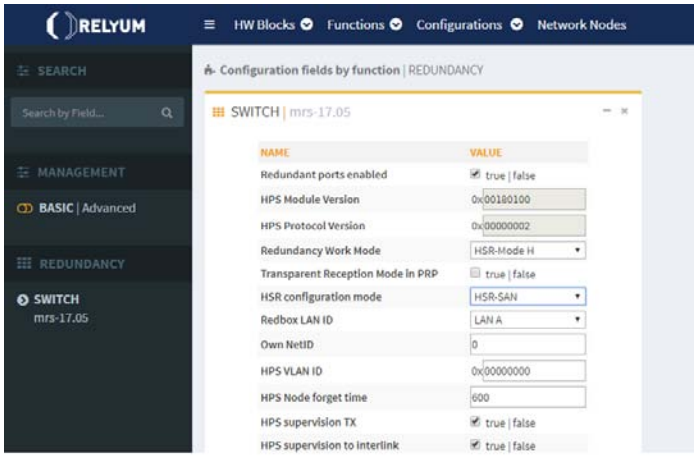

Figure 4 Snapshot of the embedded Web-based configuration tool

CONCLUSIONS

This paper has summarized the concepts of the high-availability protocols, HSR and PRP, in combination with PTP. Additionally, a ready-to-use PCIe product for seamless integration into any industrial computer is introduced. In order to illustrate the applicability of these smart devices, a real use-case has been described. The contribution presented in this paper aims to simplify and to reduce the overall costs of the implementation of HSR/PRP Networks. The

use-case presented solves a demand of integrators of High-Availability Ethernet networks: A simple interconnection of PRP and HSR Networks. It removes the need for additional intermediate RedBox external equipment and reuses the existing Gateways or PC SCADA Systems to manage the packet processing thanks to the dual functionality of DAN and RedBox embedded on **RELY-**SYNC-HSR/PRP-PCIe . **RELYUM** has born to provide innovative solutions for networking, synchronization and cybersecurity in critical systems. If you want to receive more detailed information about the solutions presented in this paper or any additional inquiry, do not hesitate to contact us at info@relyum.com.

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