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Parallel Redundancy Protocol Notably Improves Industrial Wireless Reliability

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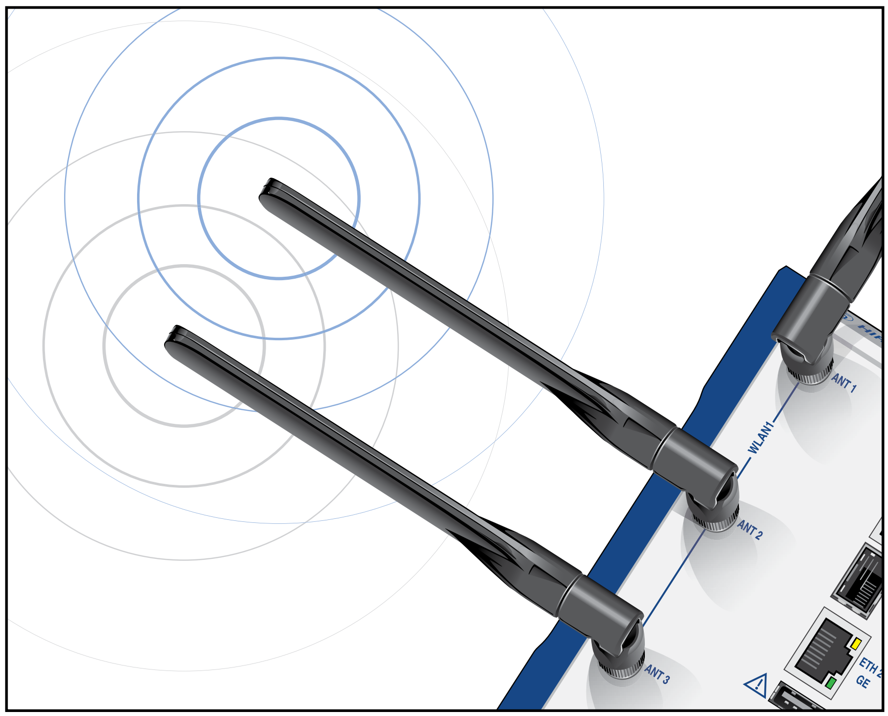
Executive Summary

Wireless solutions are often thought to be tainted by susceptibility to interference and lack of reliability. Despite recent technical improvements, wireless transmission technology still elicits concern when mission-critical processes have to be controlled or monitored via WLAN connections. However, the robustness, reliability and availability of wireless connections can be increased dramatically by using standards-based redundancy techniques, such as Parallel Redundancy Protocol (PRP). This article describes the basic technical principles, requirements and application scenarios for the application of PRP in WLAN networks.



Introduction

Wireless LAN has become an enabler for many of today's communication applications in the industry. WLAN is an excellent solution whenever using cables would be too heavy, unreliable (wear and tear), costly, or simply impossible due to moving parts and vehicles. In addition, the use of wireless on the production floor enables a completely new approach for planning and executing production processes (Industry 4.0).

The ongoing technical advances and much wider acceptance of wireless solutions in recent years is also fostering increasingly challenging and highly sophisticated application scenarios. Yet the reliability and quality of service of wireless connections can cause concern for applications with strict reliability and latency requirements.

Examples of such critical or sensitive applications include controlling production workflows or video systems with safety tasks, such as the monitoring of hazardous locations in a plant or monitoring the interior of passenger rail cars. Network interruptions can quickly lead to serious problems and consequently high follow-on costs.

PRP – Creating Redundancy by Doubling Packets

To counter network disruptions in wired industrial Ethernet networks, redundancy techniques have been established to ensure that the network continues to operate smoothly even if individual connections fail. These redundancy techniques can also be used in wireless networks in order to significantly increase the reliability and robustness of the connections.

One key example is standardized Parallel Redundancy Protocol (PRP). IEC62439 PRP is used increasingly in wired environments to enable seamless redundancy or loss-free switching in the event of failure in a network path or a device. To achieve this, data packets are duplicated and transmitted in parallel across two different and independent network paths. Before the duplicated packets are delivered beyond these network paths, the parallel streams are merged and duplicate packets are removed. If a single path fails, packets from the other path will be used. The application relying on this network can therefore continue to work without failure despite serious disruptions in the network (Figures 1 and 2 show PRP in operation).

PRP can also be used in a wireless environment, although the impact manifests itself in a completely different and even more beneficial way from in a wired scenario. This is because parallel redundancy can be used not only for total network disruptions, but can also be used to compensate for the inherent small-scale disruptions (e.g., interference) in a wireless network. When PRP transmits packets simultaneously on two different wireless transmission paths (Figure 3), the effects of individual path packet losses can be eliminated; a transmission fault or receive error on a path only becomes visible if both paths fail simultaneously for the exact same packet. In other words, uncorrelated packet losses are never seen by applications employing PRP techniques.

Although the mechanisms used by PRP are the same in both wireless and wired scenarios (packet duplication and elimination), the effect achieved is more dramatic for wireless. While use of the PRP allows a seamless switchover between two networks in both a wired and wireless scenario, its use in a wireless scenario immediately offers a number of additional advantages:

a) Compensation for individual packet losses in case of temporary disturbances, such as interference caused by other radio systems, increasing reliability dramatically.

b) Decreased latency, since the faster of the two duplicated packets is always forwarded.

c) Reduced transit time fluctuations (jitter), with b), long delays, caused by an occupied medium or by network layer retransmissions, are reduced because fluctuations only appear if both packets arrive late.

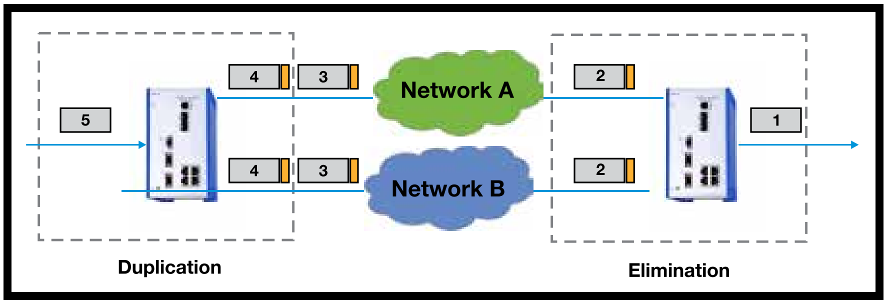


Figure 1. PRP without network failure. Two redundant paths are used simultaneously. Packets duplicated at point 5; duplicates are discarded at point 1.

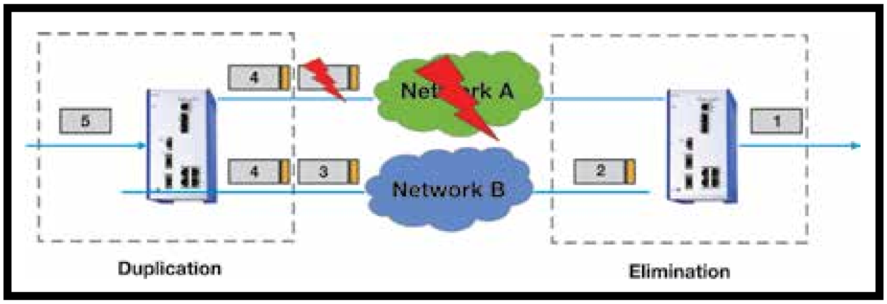


Figure 2. PRP in case of a network failure. Packets from the second network path are used without any resulting switchover times.

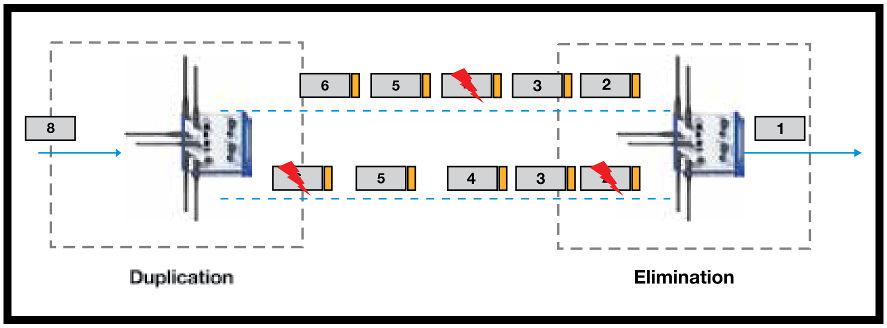


Figure 3. PRP over two WLAN transmission paths: The redundant transmission compensates for packet losses and counterbalances load and interference-related transit time differences.

Benefits in Practice

The benefits of deploying standards-based PRP can be demonstrated using a simple example: Assuming the loss rate is identical on both paths and is approximately 0.1percent, the loss rate (or loss probability) for the overall PRP system would be just 0.0001 percent (0.001 x 0.001 = 0.000001) – an improvement by a factor 1000.

This calculation assumes that losses are evenly distributed and are not correlated. To achieve this in practice, it is necessary to ensure there are no influencing factors that would impact both radio channels equally, a best practice in building reliability. A key example of this diversity is operating both paths in different frequency bands. As a result, a competing radio transmission or other environmental influences cannot affect both paths at the same time. Other factors that cause correlated losses and reduce the uniformity of the loss distribution should also be minimized. For example, permanent overloading of a connection can cause sequences of packets to be dropped, which drives up the loss rates for this connection and therefore significantly worsens the combined loss rate at the same time.

These dramatic improvements can also be achieved in reality. In practical tests, the perceptible packet loss for the application with the PRP was reduced from 0.105 percent and 0.101 percent for the individual connections to 0.00021 percent using a parallel redundant PRP connection – an approximately 500-fold improvement.

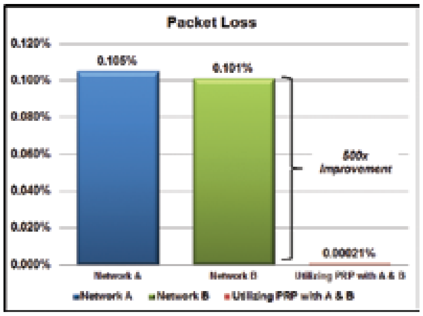


Chart 1. Packet Loss.

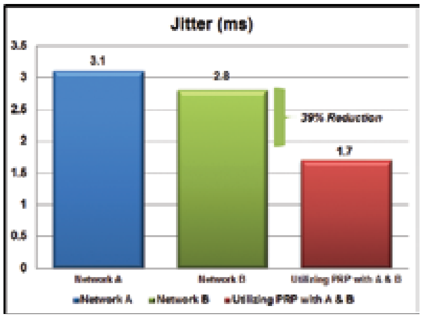


Chart 2. Jitter (ms).

Another positive effect of the use of PRP is that the network latency and transit time differences, the jitter, decrease significantly in the network. A reduction in the average latency from 3.1 ms or 2.8 ms to 1.7 ms, can be observed in practice in the above example. The jitter value likewise falls from 0.45 ms to 0.23 ms. The reason for the improvement in these metrics is that the faster of the two packets transmitted across the wireless links is always forwarded with the PRP. Outlier packets with long transmission times, as are known to occasionally occur with WLAN

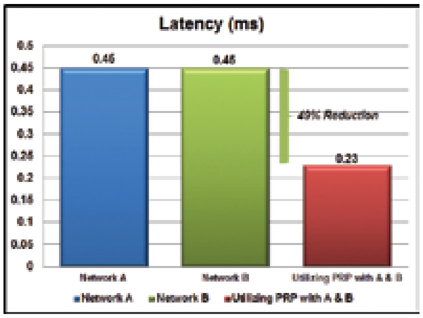


Chart 3. Latency (ms).

because of the shared medium and the non-deterministic channel access, can be largely eliminated in this way. Consequently, three of the most important quality indicators for a network (loss rate, jitter and transmission time) are improved significantly with PRP.

Topologies and Applications

While PRP represents a significant improvement in the redundant protection of individual transmission paths as outlined above, the fact that it is not limited to pure wireless transmission makes the flexibility of this standardized solution all the more obvious when it comes to complex network structures. Even though proprietary WLAN redundancy solutions potentially offer enhanced transmission performance, such improvements are always focused on an individual transmission path. Standardized PRP on the other hand allows more complex scenarios to be realized with wired and wireless Ethernet connections, as well as mobile applications with roaming devices. Figure 4 (next page) illustrates a scenario in which PRP is used over both a wired and a wireless transmission path. The wireless transmission path can therefore be used as a switchover-free backup connection for the wired path in the case of applications with difficult constraints (e.g., moving parts or high temperatures). Such a combination is not possible if proprietary WLAN redundancy solutions are used.

Figure 5 (next page) shows the use of PRP in a mobile scenario: a dual-radio client (e.g., on a moving machine or a train) travels along a path with several access points. The client can operate two connections at the same time, which means that the path can be protected with PRP.

The client can also establish the redundant connections to different access points along the route and roam from access point to access point with one of the two PRP connections remaining active at all times. Moreover, the resulting quality of the connection will always be as good or better than the best of the two connections, regardless of mobility effects (e.g., bad signal to noise ratio or fading) since the PRP algorithm automatically chooses the packets of the better link. This allows roaming interruptions and service degradation to be avoided with no switchovers. What is important in this scenario again is that PRP is not limited to the wireless channel, since various WLAN connections run over several access points connected to the network in different ways. Duplicate packets must be eliminated at a central point in the network, something that is only possible using a standardized and WLAN-independent method.

Belden and Hirschmann offer a complete portfolio of PRP-enabled devices with the switches of the RSP switch line, which allow the previously described solutions to be realized. Furthermore, as an expansion to its full line of Industrial WLAN Solutions, Hirschmann now offers Integrated PRP functionality in its OpenBAT series of access points. These 802.11n dual-radio solutions will offer this functionality as an ordering option with HiLCOS 8.90 firmware.

Conclusion

As a standardized redundancy solution, PRP is ideally suited to dramatically improving reliability and the quality of service of wireless connections. In addition, PRP allows a variety of network topologies comprising wired and wireless connections to be protected. As a result, loss- and latency-sensitive applications can successfully be operated over wireless connections.

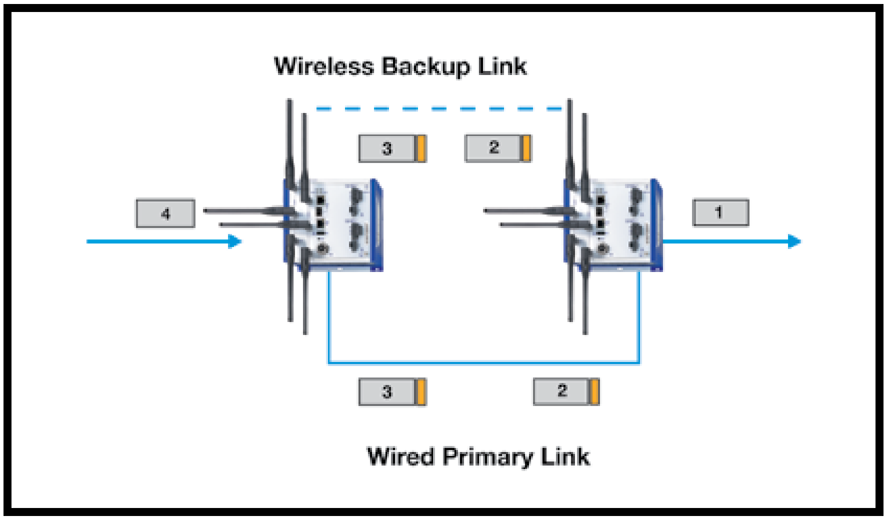


Figure 4. PRP allows both wired and wireless routes to be used as redundant paths, thereby enabling a variety of network topologies. Shown here is a wired path with a wireless backup path.

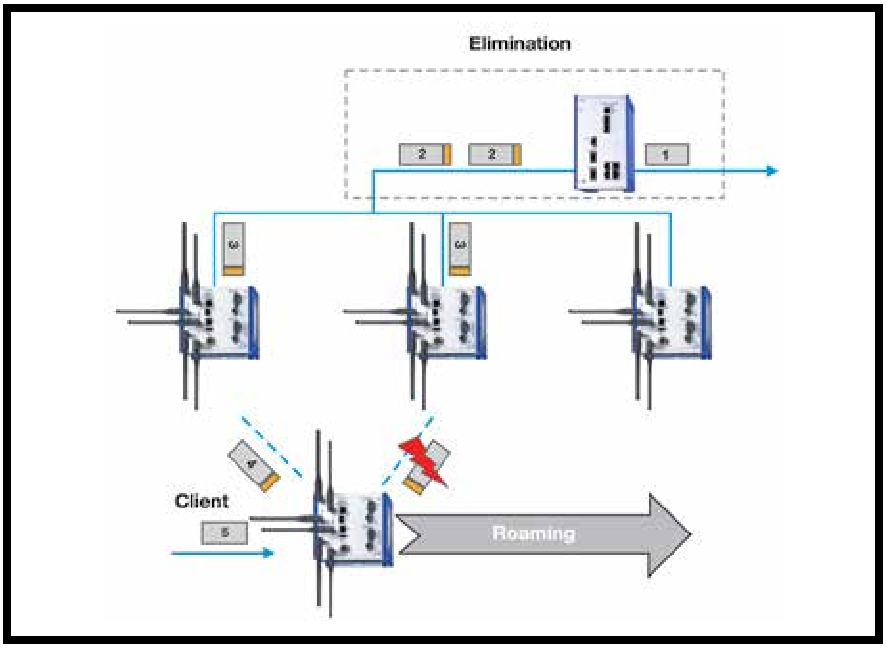


Figure 5. PRP in a WLAN network comprising several access points and a client. Elimination is performed at a central location with a PRP-enabled switch.