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Error Mitigation in Industrial Wireless Sensor Networks:
Corrupted Packet Forensics and Recovery

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Wireless sensor networks (WSN) are gradually penetrating the industrial automation domain. This process is, however, inhibited by a number of challenges that need to be considered and addressed before WSN can serve the most demanding industrial applications. In the context of process automation, existing technology can only serve the three least critical application classes related to non-critical monitoring of slowly-changing physical variables. The main issue in that respect is the insufficient communication timeliness and reliability, caused by the influence of harsh radio environment and the infeasibility of applying advanced communication techniques, due to the poor computational power of low-cost specialized hardware.

The goal of this work is to improve wireless communication reliability in industrial environments, where the proposed solutions are generally applicable to other WSN domains as well as radio environments. This research is based on the notion that corrupt packets contain valuable channel state information that can be leveraged to improve communication robustness. The research methodology used in this work is rather unconventional, compared to existing research, but also highly intuitive, bearing in mind that counteracting a phenomenon requires a thorough knowledge of its properties. In order to rectify the aforementioned challenges, this work makes the following three contributions.

The first contribution is a comprehensive analysis of communication errors recorded in practically relevant scenarios in a number of industrial environments. The related literature is seemingly rich, but essentially poor, due to inadequate measurement objectives, environments, and scenarios. The main research outcome of this measurement campaign is a set of practically relevant conclusions, which can be used for the design of coding, interleaving and packet recovery schemes.

The second contribution is the design of two packet recovery schemes, based on the knowledge about error patterns obtained in the industrial measurement campaign. The first scheme is a proposal for redefinition of the IEEE 802.15.4 physical layer, where digital errors are counteracted at the earliest stage in the receiver chain. The second scheme exploits the determinism in packet structure inherent to industrial communication. Both schemes significantly improve the correctability of corrupted packets received.

The third contribution is a channel diagnostics algorithm that determines whether a packet was corrupt by multipath fading and attenuation or by wireless local area network interference. The algorithm is derived from the error traces collected in three industrial environments and tested at a fourth, previously unused, industrial site. The results of live tests verify the ability of the proposed algorithm to promptly reestablish communication after a sudden deterioration of channel quality.

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