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Sensible Things that Communicate

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A Protocol Framework for Adaptive Real-Time Communication in Industrial Wireless Sensor and Actuator Networks

Author doctoral thesis: Wei Shen

STC Research Center a part of Mid Sweden University

Abstract:
Low-power and resource-constrained wireless technology has been regarded as an emerging technology that introduces a paradigm shift in a wide range of applications such as industrial automation, smart grid, home automation and so on. The automation industry has significant contributions to economic revenues, job opportunities and world-class research. The low-power and resource-constrained wireless technology has brought new opportunity and challenges for industrial automation. The solutions of such wireless technology offer benefits in relation to lower cost and more flexible deployments/maintenances than the wired solutions, and new applications that are not possible with wired communication. However, these wireless solutions have been introducing new challenges. Wireless links are inherently unreliable, especially in industrial harsh environment, and wireless interference makes the problem even worse. Low-power consumption is required and real-time communication is generally crucial in industrial automation applications.

This research work addresses that industrial wireless sensor and actuator network (IWSAN) should even be designed to provide service differentiation for wireless medium access and adapt to link dynamics for scheduling algorithms on top of real-time services. Specifically, exceeding the required delay bound for unpredictable and emergency traffic in industrial automation applications could lead to system instability, economic and material losses, system failure and, ultimately, a threat to human safety. Therefore, guaranteeing the timely delivery of the IWSAN critical traffic and its prioritization over regular traffic (e.g. non-critical monitoring traffic) is a significant topic. In addition, the state-of-the-art researches address a multitude of objectives for scheduling algorithms in IWSAN. However, the adaptation to the dynamics of a realistic wireless sensor network has not been investigated in a satisfactory manner. This is a key issue considering the challenges within industrial applications, given the time-constraints and harsh environments.

In response to those challenges, a protocol framework for adaptive real-time communication in IWSAN is proposed. It mainly consists of a priority-based medium access protocol (MAC) and its extension for routing critical traffic, a hybrid scheme for acyclic traffic, and adaptive scheduling algorithms. To the best of our knowledge, the priority-based MAC solution is the first priority-enhanced MAC protocol compatible with industrial standards for IWSAN. The proposed solutions have been implemented in TinyOS and evaluated on a test-bed of Telosb motes and the TOSSIM network simulator. The experimental results indicate that the proposed priority-based solutions are able to efficiently handle different traffic categories and achieve a significant improvement in the delivery latency. The hybrid scheme for acyclic traffic increases the throughput and reduces the delay compared to the current industrial standards. Numerical results show that the adaptive scheduling algorithms improve the quality of service for the entire network. They achieve significant improvements for realistic dynamic wireless sensor networks when compared to existing scheduling algorithms with the aim to minimize latency for real-time communication.