

Recent and Emerging Topics in Wireless Industrial Communications: A Selection

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Abstract

In this paper we discuss a selection of promising and interesting research areas in the design of protocols and systems for wireless industrial communications. We have selected topics that have either emerged as hot topics in the industrial communications community in the last few years (like wireless sensor networks), or which could be worthwhile research topics in the next few years (for example cooperative diversity techniques for error control, cognitive radio / opportunistic spectrum access for mitigation of external interferences).

Index Terms

Wireless sensor networks, IEEE 802.15.4, ZigBee, spatial and cooperative diversity, cognitive radio, industrial-QoS, ultra-wideband

I. INTRODUCTION

For most people the significance of wireless technologies comes from its ability to provide services like voice / video transmission or Internet access at places without cabled networking infrastructure or while being on the move. Wireless technologies have also been identified as a very attractive option for industrial and factory automation, distributed control systems, automotive systems and other kinds of networked embedded systems [1], [2], with mobility, reduced cabling and installation costs, reduced danger of breaking cables, and less hassle with connectors being important benefits. Some potentially interesting classes of industrial applications are closed-loop control involving mobile subsystems, coordination among mobile robots or autonomous vehicles, health monitoring of machines, tracking of parts and many more. An important characteristic in these application areas is that (wireless) data communications must satisfy tight real-time and reliability requirements *at the same time*, otherwise loss of time and money or even physical damage can result. To achieve this goal, on the one hand certain functionalities that are specific for wireless communications (like mobility management, quick handovers) must be considered, and on the other hand the unfriendly error properties of the wireless channel significantly challenge real-time and reliability. Consequently, significant research is needed to adapt existing wireless technologies and protocols to industrial settings, or, when this is not sufficient, to develop new ones. This research has been done with significant

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intensity for more than one decade now, and in [1] a selective review and tutorial on research issues and approaches has been given.

This paper is a followup to [1]. Our main goal is to discuss a selection of promising and interesting research areas that received no or only limited coverage in [1] and in the industrial communications community. We start with a brief overview on the the quality-of-service features that have been added to the ubiquitous IEEE 802.11 wireless LAN standard and which are also interesting for use in industrial scenarios. Following this, the paper covers wireless sensor networks. Wireless sensor networks have recently received increased attention in the industrial communications community. They differ considerably from wireless LANs. Sensor networks support much lower data rates and much smaller transmit powers. More fundamental to the design of sensor networks, however, is that sensor nodes have a severely limited energy budget and consequently energy-efficiency is the single most important figure of merit. One consequence of this is that sensor nodes should spend most of their time in a sleep state in which they are not able to transmit or receive data. These properties do not favor the adoption of sensor networks in tight control loops. Instead, they are mostly considered for less time-critical monitoring tasks like for example monitoring machine health or leakage monitoring. We provide an introduction to important concepts of sensor networking and discuss a number (by far not all) of protocol design issues that are relevant for industrial applications.

In the second main part of this paper we discuss approaches that we believe can have a significant impact on the future design of wireless industrial communication protocols. In particular, we introduce recent techniques to mitigate channel fading and external interferences (two of the main reasons for the bad quality of the wireless channel!) that are currently hot topics in the wireless communications community and from which the industrial networking community can significantly benefit. For the sake of completeness we have also included a brief discussion of an existing commercial systems for wireless industrial communications: the WISA system from ABB.

We had to make choices on what to include in the paper. In terms of protocols we have mostly favored topics related to the lower layers of the industrial protocol stack (i.e. the MAC and the link-layer with its error control functionality) and their properties in terms of real-time and reliability. We have furthermore favored a tutorial-style exposition discussing fundamental issues and solution approaches over the detailed discussion and comparison of specific solutions from the literature. To help the reader to delve further into these solutions and approaches, we provide a fair number of references. We also aim to point out interesting research questions.

The paper is structured as follows: in the next Section II we provide a broad overview on the general research areas that need to be addressed for wireless industrial networking. Since the focus of the remaining paper is mostly on real-time and reliability properties, we also discuss appropriate performance measures. Following this, in Section III we describe the quality-of-service enhancements to the IEEE 802.11 standard and point to an interesting research issue. In Section IV we begin our discussion of wireless sensor networks by explaining their fundamentals. In Section V we present the IEEE 802.15.4, ZigBee and ISA SP-100 standards for wireless sensor networking, since these can be expected to have significant impact in the industrial field. In Section VI we briefly look at the vast problem of providing real-time and reliability in multi-hop wireless sensor networks. The first part of the paper concludes

with Section VII, in which the existing wireless industrial communication systems WISA is briefly reviewed.

In the second part we discuss more general research issues and selected topics from the field of wireless communications that are probably relevant for wireless industrial communication systems as well: spatial / cooperative diversity techniques in Section IX, the general issue of industrial Quality-of-Service provisioning and analysis in Section X, the usage of cognitive radio techniques for mitigating external interferences in Section XI and the adoption of ultra-wideband technologies in Section XII. The paper ends with our conclusions in Section XIII.

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