Guest Editorial

HETEROGENEOUS networks, frequently consisting of (partially homogeneous) local and wide-area systems, as well as wired and wireless communication systems, will become increasingly important. Future scenarios of distributed automation require mechanisms for geographically distributed automation functions due to various reasons:

1) centralized supervisory and control of (many) decentralized (small) technological plants;
2) remote control, commissioning, parameter setting, and maintenance of distributed automation systems;
3) support of energy efficiency approaches by means of distributed control concepts;
4) inclusion of remote experts or external machine-readable knowledge for the plant operation and maintenance (i.e., asset management and condition monitoring).

Digital networking in industrial automation has a long history. For the last two decades, digital communications have been widely introduced in distributed computer control systems within both the factory and the process domain. Fieldbus systems and sensor bus systems supplemented and partially displaced the proprietary communication systems within supervisory control and data acquisition systems. The introduction of fieldbus systems has been associated with a change of paradigm to deploy industrial automation systems. Nowadays, (wired) fieldbus systems are standardized and the most important communication system used in commercial control installations. At the same time, Ethernet became the most frequently used communication technology within the office domain. However, for the last five years, and increasingly so more recently, there has been a growing tendency to introduce Ethernet-based real-time communication systems into the industrial automation domain. This domain is dominated by harsh environments, as well as by real-time and safety-critical requirements. Ethernet-based solutions are dominating as a merging technology. In the meantime, wireless communications have been introduced in both the office environment and the workshop area. The usage of wireless technologies has been increasingly investigated and standardization is continuing.

Following the trend to merge the automation and office networks, heterogeneous networks, consisting of local and wide-area, wired, and wireless communication systems are becoming important. In analogy to the expression "Virtual Private Network" (VPN) within the office domain, we define a "Virtual Automation Network" (VAN) describing the adaptation of the heterogeneous network infrastructure including the mechanisms of VPN on the automation requirements. A VAN consists of domains covering common application contexts (automation tasks) equipped with their specific distributed devices that are connected via the heterogeneous network.

Wireless sensor networks (WSNs) are working within a limited location and can represent industrial subnetworks within a VAN. The VAN infrastructure is able to connect these subnetworks via a runtime tunnel that can be established using a web-based and name-oriented addressing scheme. Once a runtime tunnel has been established, the data exchange between devices of the geographically distributed WSNs can take place.

The main requirements for communication systems within industrial automation are the following.

1) Real-time behavior. There are different applications (nonreal-time applications, i.e., diagnosis, maintenance, commissioning, and slow mobile applications; soft real-time applications, i.e., processes in manufacturing and process automation and data acquisition; hard real-time applications, i.e., control applications, fast mobile applications, and machine tools; and isochronous hard real-time applications, i.e., motion control).
2) Functional safety. This refers to protection against hazards caused by incorrect functioning, including communication via heterogeneous networks. There are several safety integrity levels.
3) Security. This requires a common security concept for distributed automation using a heterogeneous network with different security integrity levels (not existing yet).
4) Noninterrupted availability.
5) Location awareness. The desired context awareness leads to the usage of location-based communication services and context-sensitive applications.
6) Energy efficiency.

These requirements have to be fulfilled by wireless communications, too. There are two important international standardization activities going on. The Instrument Society of America (ISA) SP100.11a (ISA SP100.3) Working Group for Wireless Industrial Automation Networks published a first version of a standard for wireless systems for industrial automation: process control and related applications. The International Electrotechnical Commission (IEC) TC65 started a standardization activity based on IEC/Publicly Available Specification 62591 that describes the WirelessHART specification which is part of HART version 7.1. Various vendors are currently launching WSN products into the market. However, WSN is an ongoing subject of research and the international acceptance of WSN in the industrial environment is in its initial phase.

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We offer this "Special Section on Industrial Wireless Sensor Networks" as an attempt to provide some feedback on recent advances and technical challenges facing the adoption of this technology. The section includes a diverse selection of five papers, and we trust that these will give the reader some insight into the current state.

The first paper, entitled "Industrial Wireless Sensor Networks: Challenges, Design Principles, and Technical Approaches," aims at providing a contemporary look at the current state of the art in IWSNs and discusses the still-open research issues. It presents the case that industrial WSNs (IWSNs) offer several advantages over traditional wired industrial monitoring and control systems, including self-organization, rapid deployment, flexibility, and inherent intelligent processing capability. In nowadays' competitive industry marketplace, pressure is building to improve process efficiencies, comply with environmental regulations, and meet corporate financial objectives. Given the aging of many industrial systems and the competitive industrial manufacturing market, intelligent, flexible, and low-cost industrial automation systems are required to improve the productivity and efficiency of such systems. IWSN has the potential to play a vital role in creating a highly reliable and self-healing system that rapidly responds to real-time events with appropriate actions. The paper goes on to present challenges, design principles, and technical approaches in terms of hardware and software development, system architectures and protocols, and progress with regard to the development of applicable standards.

In the second paper, "Which Wireless Technology for Industrial Wireless Sensor Networks? The Development of OCARI Technology," the development of an IWSN technology called optimization of communication for *ad hoc* reliable industrial (OCARI) networks, is presented. This system is specifically directed at applications in harsh environments, such as power plants. It is a wireless communication technology that supports mesh topology and a power-aware *ad hoc* routing protocol for maximum network lifetime. It is based on the IEEE 802.15.4 PHY layer with a deterministic MAC layer for time-constrained communication. During the nontime-constrained communication period, it uses an energy-aware Optimized Link State Routing Protocol proactive routing protocol. The OCARI application layer is based on ZigBee APS and APL primitives and profiles to ensure maximum compatibility with ZigBee applications. This technology is extensively tested in industrial facilities and the ultimate goal is to offer this specification as an open standard.

Wireless interface for sensors and actuators (WISA), with its two subconcepts WISA-power and WISA-com, is regarded as a system for providing reliable wireless communication in problematic parts of the field network, as well as addressing the increasing wiring cost and cable wear and tear, with the growing number of field devices in the manufacturing industry. The next paper, "Integration of a Wireless I/O Interface for PROFIBUS and PROFINET for Factory Automation," proposes amendments to WISA, which claim to improve 802.11b/g coexistence and harmonize integration of WISA for sensor/actuator communication in, e.g., PROFINET IO systems. The suggested improvements relate to both the radio protocol for improving coexistence with other wireless technologies, as well as to concepts for integrating WISA into the field-network of PROFINET/PROFIBUS.

Most industrial wireless applications are designed with multiple backbone routers (BbRs) to enhance reliability, as this practice offer significant benefits, such as spatial diversity and load balancing. The fourth paper, entitled "Exploiting Backbone Routing Redundancy in Industrial Wireless Systems" investigates the advantages of spatial diversity provided by multiple BbRs. BbR-related communication patterns and mesh routing mechanisms optimizing the effects of spatial diversity are shown, and the quantitative effectiveness of redundancy of multiple BbRs is clarified with experimental proofs.

The final paper describes "Simple Pedestrian Localization Algorithms Based on Distributed Wireless Sensor Networks." In this paper, simple localization algorithms for reducing the noise effects and disturbances without *a priori* knowledge are proposed and validated through actual experimental tests.

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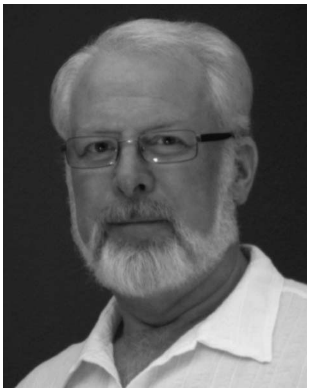

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