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From Wireline to Wireless Networks and Technologies

The advances in design of embedded systems, tools availability, and falling fabrication costs of semiconductor devices and systems allowed for infusion of intelligence in to field devices such as sensors and actuators. The controllers used with these devices typically provide on-chip signal conversion, data and signal processing, and communication functions. The increased functionality, processing and communication capabilities of controllers have been largely instrumental, among other factors, in the emergence of a widespread trend for networking of field devices around specialized networks, frequently referred to as field area networks

The field area networks, or fieldbuses [1] (fieldbus is, in general, a digital, two-way, multi-drop communication link) as commonly referred to, are, in general, networks connecting field devices such as sensors and actuators with field controllers (for instance, programmable logic controllers (PLCs) in industrial automation, or electronic control units (ECUs) in automotive applications), as well as man-machine interfaces, for instance, SCADA in industrial automation or dashboard displays in cars.

In general, the benefits of using those specialized networks are numerous, including increased flexibility attained through combination of embedded hardware and software, improved system performance, and ease of system installation, upgrade, and maintenance. Specifically, in automotive and aircraft applications, for instance, they allow for a replacement of mechanical, hydraulic, and pneumatic systems by mechatronic systems, where mechanical or hydraulic components are typically confined to the end-effectors; just to mention these two different application areas.

Unlike LANs, due to the nature of communication requirements imposed by applications, field area networks, by contrast, tend to have low data rates, small size of data packets, and typically require real-time capabilities which mandate determinism of data transfer. However, data rates above 10 Mbit/s, typical of LANs, have become a commonplace in field area networks.

The specialized networks tend to support various communication media like twisted pair cables, fiber optic channels, power line communication, radio frequency channels, infrared connections, etc. Based on the physical media employed by the networks, they can be in general divided in to three main groups, namely: wireline based networks using media such as twisted pair cables, fiber optic channels (in hazardous environments like chemical and petrochemical plants), and power lines (in building automation); wireless networks supporting radio frequency channels, and infrared connections; and hybrid networks composed of wireline and wireless networks.

Although the use of wireline based field area networks is dominant, the wireless technology offers a range of incentives in a number of application areas. In industrial automation, for instance, wireless device (sensor/actuator) networks can provide a

support for mobile operation required in case of mobile robots, monitoring and control of equipment in hazardous and difficult to access environments, etc. In a wireless sensor/actuator network, stations may interact with each other on a peer-to-peer basis, and with a base station. The base station may have its transceiver attached to a cable of a (wireline) field area network, giving rise to a hybrid wireless- wireline system [2]. A separate category is the wireless sensor networks, envisaged to be largely used for monitoring purposes.

Although potential applications in the projected areas are still under discussion, the wireless sensor/actuator networks are in the deployment stage by the manufacturing industry. A wireless communication system to operate effectively in the industrial/factory floor environment has to guarantee high reliability, low and predictable delay of data transfer (typically, less than 10 ms for real time applications), support for high number of sensor/actuators (over 100 in a cell of a few meters radius), and low power consumption, to mention some. In the industrial environments, the characteristic for the wireless channel degradation artifacts can be compounded by the presence of electric motors or a variety of equipment causing the electric discharge, which contribute to even greater levels of bit error and packet losses. One way to partially alleviate the problem is either by designing robust and loss-tolerant applications and control algorithms, or by trying to improve the channel quality; all subject of extensive research and development [3].

To leverage low cost, small size, and low power consumptions, standard Bluetooth (IEEE 802.15.1) 2.4 GHz radio transceivers may be used as the sensor/actuators communication hardware. To meet the requirements for high reliability, low and predictable delay of data transfer, and support for high number of sensor/actuators, custom optimized communication protocols may be required as the commercially available solutions such as Bluetooth (IEEE 802.15.1), IEEE 802.15.4, and IEEE 802.11 variants may not fulfill all the requirements. A representative example of this kind of systems is a wireless sensor/actuator network developed by ABB and deployed in a manufacturing environment [4]. The system, known as WISA (wireless sensor/actuator) has been implemented in a manufacturing cell to network proximity switches, which are some of the most widely used position sensors in automated factories to control positions of a variety of equipment, including robotic arms, for instance.

In recognition of the importance of the wireless technologies in factory and industrial automation, a special section has been organized to give a broad cross-section of the activities in this area by focusing on both research and deployment aspects of the technologies under treatment. The material of the section has been divided between the May and August issues. This arrangement was adopted to avoid for one specific technical area to dominate a single issue. The general objective is to publish material to reflect a broad range of technical interests of the journal's readers. This, May 2007, issue includes papers on wireless and wireline technologies in factory communication systems, asynchronous communication protocol, robotics, control of overhead cranes, and business process networks.

The journal has embarked on a program of publishing research survey papers to provide a comprehensive overview of the emerging areas of technology and to serve as a major source of references to cover the most important research developments and results. All that critically evaluated and presented in the context of the emerging trends. Some of the areas covered include the Platform Based Design of embedded and wireless systems, wireless technology in factory and industrial automation, real-time Ethernet, networked embedded systems, security in embedded systems, performance evaluation of manufacturing systems, and integration issues in industrial automated systems, to mention some. We have enlisted as the authors some of the leading experts from UC Berkeley, Technical University of Berlin, Centre Suisse d'Electronique et de Microtechnique (Switzerland), UC San Diego, University of Patras, and INRIA (France), and Austrian Academy of Sciences. The aim of this program is to help practitioners and researches navigate in the fast accumulating body of knowledge and look for important and emerging trends. The first invited paper is scheduled for a publication in the November 2007 issue.

[1] Thomesse J-P., "Fieldbus Technology in Industrial Automation", Special Issue on Industrial Communication Systems, *Proceedings of the IEEE*, ed. R. Zurawski, 93(6), June 2005, pp. 1073-1101.

[2] Decotignie, J.-D., "Interconnection of Wireline and Wireless Fieldbuses", Industrial Communication Technology Handbook, CRC Press/Taylor & Francis, ed. R. Zurawski, 2005., pp. 26.1 –26.13.

[3] Willig, A., Wolisz, A., Mattheus, K., "Wireless Technology in Industrial Networks", Special Issue on Industrial Communication Systems, *Proceedings of the IEEE*, ed. R. Zurawski, 93(6), June 2005, pp. 1130–1151,

[4] Dacfez Dzung, Jan Endresen, Christoffer Apneseth, Jan-Erik Frey, "Design and Implementation of a Real-Time Wireless Sensor/Actuator Communication System", Proceedings 10th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2005), Catania, Italy, 2005, Vol.2, pp.433-442.

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