Guest Editorial

A comprehensive automation of factories, plants, and enterprises, an elusive goal for decades, is becoming closer and closer every year as the existing and emerging technologies offer new solutions, products, and complete systems. Information technology and industrial communication systems play an increasingly important role in attaining this goal. They bring closer the prospect of vertical integration of systems, factories, plants, and enterprises from the sensor to the decision-making level. This integration will allow for a comprehensive process-data publishing which is a prerequisite for efficient control, decision-making, and management.

Over two decades ago, the common approach to industrial communication was based on using circuit-switching propriety networks. The 1990s saw plants turn to packet-switching standardized networks, or fieldbuses. To mention some which became international standards: Controlnet, FIP/WorldFIP (Fieldbus Internet Protocol), Foundation Fieldbus, Interbus-S, Profibus (Process Fieldbus), P-NET. In general, fieldbus is a generic term which describes a communications network used to link isolated field devices, such as controllers, transducers, actuators, and sensors. We should also mention here Controller Area Network (CAN) which has received a great deal of attention from the academic community. CAN is a serial bus system especially suited for embedded applications such as machine control, in-vehicle, and railway applications. In the U.S., the CAN-based DeviceNet is one of the most successful networks for factory automation. An emerging star in the area of industrial networks is EtherNet/IP which supports Internet-based access to enterprisewide components and information. The main reasons for the migration to packet-switching networks were the cost and better utilization of the network resources. Standardization allows for designing and building by various vendors specific network technology compatible controllers, devices, machines, and machinery and, thus, promotes industrial system growth without being tied up to one vendor propriety technology.

This "Special Section on Factory Communication Systems" aims at presenting a sample of the current research activities in the area of industrial networks. Some of the submissions are extended versions of papers presented at the 3rd IEEE Workshop on Factory Communication Systems held in Portugal in 2000. The papers are divided into three main groups: New Protocols and Extensions (four papers), Analysis and Simulation Methods and Tools (two papers), and Wireless Technology (one paper). The papers are introduced through an overview of the issues they address.

New Protocols and Extensions

The flexibility requirement for industrial communication systems, in terms of online additions, removal, and adaptation of message streams, is becoming increasingly an important one. This is motivated by the need to reduce the cost of setup, configuration changes, and maintenance to mention a few aspects. Fieldbuses, however, either guarantee time-constrained services at the expense of reduced flexibility, or such guarantees are sacrificed in exchange for higher flexibility. Another important requirement centers around the need for fieldbuses to deliver both time-triggered and event-triggered communication services under time constraints. The existing fieldbus systems tend to privilege one of the two services either inefficiently handling event-triggered services, or compromising the temporal requirements of time-triggered services. These issues are addressed in the first paper in this Special Section, "The FTT-CAN Protocol: Why and How," by L. Almeida, P. Pedreiras, and J. A. Fonseca. This paper discusses a new protocol called Flexible Time-Triggered communication on Controller Area Network. FTT-CAN supports time-triggered communication in a flexible way and offers an efficient combination of time-triggered and event-triggered traffic with temporal isolation while maintaining the desired properties of both types of traffic. This is achieved by introducing Synchronous and Asynchronous Messaging Systems which handle time- and event-triggered communication, respectively.

Under heavy traffic conditions, when the bus utilization approaches 100%, the CAN cannot provide the same quality of service (QoS) to groups of nodes. The high-priority nodes may monopolize the available bandwidth, excluding other stations from accessing the bus. Also, it is not possible to ensure deterministically bounded transmission delays in every traffic condition. Those two issues are tackled in the second paper, "Achieving Round-Robin Access in Controller Area Networks," by G. Cena and A. Valenzano. This paper presents a modification of the CAN protocol which is called Medium Utilization State Tracking, or MUST. It employs a number of priority classes. Nodes belonging to each priority class are granted a round-robin service policy. MUST behaves much like a collision sense multiple access (CSMA) network under low-traffic conditions, and achieves performance similar to the token-based network when the offered load increases.

Several timed-token-like protocols can support real-time applications, but the presence of the ring latency may significantly reduce the utilization of the bandwidth. To overcome this problem, a new real-time protocol is introduced in the third paper, "Design and Analysis of RT-Ring: A Protocol for Supporting Real-Time Communications," by M. Conti, L. Donatello, and M. Furini. The paper describes RT-Ring protocol which supports both real-time and generic traffic (non-real time) over a ring network. The protocol is provided with concurrent network access and special reuse policy which allow the protocol to achieve high network utilization. RT-Ring also offers transmission guarantees for real-time traffic. In addition, the proposed protocol is compatible with the emerging Differentiated Service Architecture (DSA).

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The CAN protocol arbitration scheme, in addition to the lack of fairness (which was discussed in the paper, "Achieving Round-Robin Access in Controller Area Networks," by G. Cena and A. Valenzano, in this Special Section), has another drawback. In order for the arbitration scheme to work correctly, it is necessary for the network extension to be sufficiently short. In case of a transmission speed of 500 kb/s, CAN specification recommends a maximum bus length of 100 m, which is less than what other fieldbus networks allow for. A potential solution is proposed in the fourth paper, "A Multistage Hierarchical Distributed Arbitration Technique for Priority-Based Real-Time Communication Systems," also by G. Cena and A. Valenzano. This paper proposes a new real-time protocol called WideCAN which was evolved from CAN, and its variants, namely, FastCAN and StarCAN, also proposed by the authors. WideCAN is based on the tree topology and employs a multistage hierarchical arbitration technique that allows for a substantially larger network extension.

Analysis and Simulation Methods and Tools

The schedulability analysis of hard real-time systems aims at investigating whether some deadlines are met in the worst case scenario, which actually may not occur during the lifetime of the system. The failure to meet the deadlines necessitates the system redesign to secure additional resources to meet the requirements. The models employed in the schedulability analysis typically assume "normal conditions" of the system operation, i.e., no hardware or software failures, or unanticipated behavior of the system environment. The "abnormal conditions" are considered during the system reliability analysis, which is typically conducted separately from the schedulability analysis. An approach to the integration of schedulability and reliability analysis is presented in the fifth paper, "Integrating Reliability and Timing Analysis of CAN-Based Systems," by H. Hansson, T. Nolte, C. Norstrom, and S. Punnekkat. This paper presents a method that allows for a controlled relaxation of the timing requirements of safety-critical hard real-time systems, and is focused on CAN-based systems. By integrating hard real-time schedulability with the reliability analysis, this method yields a more accurate reliability analysis framework with results helping to make better design tradeoff decisions.

Validation and optimization of complex systems designed around control networks were typically performed on the prototype. However, the market conditions necessitate shortening of the time to market, and reducing the design cost. This can be achieved by employing analytical and/or simulation approaches. The analytical techniques, which yield approximate results due to simplifying assumptions, help separate design options unlikely to meet performance requirements from the ones to be subject to more detailed study, most likely using simulation techniques. The sixth paper, "Analysis and Simulation Methods for Performance Evaluation of a Multiple Networked Embedded Architecture," by P. Castelpietra, Y.-Q. Song, F. Simonot-Lion, and M. Attia, discusses a simulation framework and tools developed to study in-vehicle embedded systems designed around control networks. The framework adopts a modular approach to modeling and simulation. This allows for rapid model construction and reconfiguration of its components. In addition, the presence of a library of basic prebuilt components with well-defined interfaces allows for automatic construction of executable models.

Wireless Technology

There is a growing interest in the use of wireless transmission technologies in industrial automation. Some of the main advantages of wireless technologies are mobility, simplified installation, reliability, security, and cost. However, the existing wireless technologies and protocols are not suitable for hard real-time requirements imposed by industrial automation. Therefore, there is a need to design and develop new specialized protocols, especially for medium access control and link layer. To design medium access control and link layer protocols, it is important to understand the error pattern of the wireless link. This knowledge helps select appropriate features of the protocol. Stochastic models are used to study protocols using simulation before performing measurements on a prototype. It is important to parameterize those models using actual data generated by measurements. These issues are addressed in the last paper of the Special Section, "Measurement of a Wireless Link in an Industrial Environment Using an IEEE 802.11-Compliant Physical Layer," by A. Willig, M. Kubisch, C. Hoene, and A. Wolisz. In order to understand error patterns and find parameters for stochastic error models, measurements of wireless link error characteristics were performed in an industrial environment. The paper also discusses some implications of the results obtained on the design of medium access control and link layer protocols of future industrial wireless local area networks.

I trust that this first "Special Section on Factory Communication Systems" will be followed by more similar Special Sections, as new research results and developments in the field emerge very quickly.

I would like to thank all authors of papers submitted for consideration for publication for their contribution. I also would like to thank all reviewers for their meticulous review work which contributed significantly to the quality of the presented work. As this Special Section was in preparation for quite some time, I would like to thank Prof. J. Holtz, past Editor-in-Chief, for approving it, and Prof. F. Harashima, present Editor-in-Chief, for giving a "green light" to continue with the preparations.

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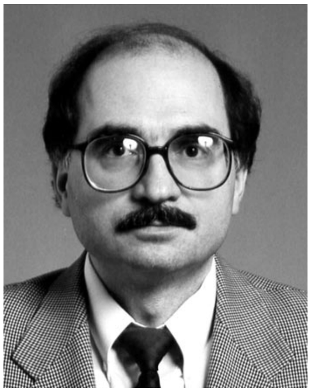

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