Scanning the Issue

Special Issue on Sensor Networks and Applications

Microsensor network technology will have a significant impact on our lives in the 21st century. Microsensor devices, ranging in size from cubic inches to cubic millimeters, will each have multiple on board miniaturized sensors (such as for light, temperature, humidity, acoustics, imaging, etc.), with considerable processing power, in each geographic position ability through global positioning systems (GPSs) or local positioning methods, and short range radio or optical communication links. These devices, which will be cheap and smart, can be deployed in small or very large numbers to instrument homes and highways, buildings and bodies, cities and infrastructures, as well as for monitoring and controlling defense applications.

The technology evolution and convergence of microelectromechanical sensors (MEMS) processing and communication will march toward hardware miniaturization and integrated sensing, computing, and communication chips. The daunting research task, however, is to develop algorithms, network protocols, and software that will enable the design of useful, long-lasting, reliable, survivable, and programmable systems out of such microsensor network devices. This research agenda requires creating new frameworks that bring together in innovative ways many disciplines, including distributed computing, networking, signal and information processing, reliability, and robust system design.

In this regard, the design of microsensor networks needs to address some key technical challenges: 1) efficient networking methods that enable rapid, ad hoc networking of any number of such devices, either fixed in location or mobile; 2) methods for collaborative signal and information processing within the network to detect, classify, and track events and patterns of events occurring in the geographic area; 3) design of distributed microdatabases of information about events of interest over a spatio-temporal interval, stored in the devices, which can be queried by multiple users; 4) methods for programmability of the network; and 5) methods for security and information assurance within the network that enables intrusion detection, intrusion tolerance, and survivable operation in the face of failure and compromise. In addition, all these methods and designs must be power efficient to ensure the maximum operational lifetime of the network. These research challenges, along with effective hardware design, will continue to challenge the research community over the next several years.

This special issue contains several important papers that address the formulation of some of the critical challenges described above, including preliminary results. While acknowledging its limited coverage, this special issue offers a range of interesting contributions such as collaborative signal processing, distributed networking, mobility, and ad hoc routing aspects of the sensor network. Let us begin our excursion with these contributions.

The first paper, "Coherent Acoustic Array Processing and Localization on Wireless Sensor Networks," by Chen *et al.*, considers the problem of coherent acoustic sensor array processing and localization using distributed wireless sensor networks. It is most interesting that by using low-cost COTS equipment, wireless acoustic testbeds using iPAQs can be implemented to perform two advanced beamforming and localization algorithms, including fine-grain synchronization for wide-band sources. Various field measurements using the testbeds show the effectiveness of the systems.

In the second paper, "Distributed Target Classification and Tracking in Sensor Networks," by Brooks *et al.*, the authors investigate the interaction between distributed signal processing and networking in sensor networks. The paper argues that there must be a close coupling between the design of the network and the application. To facilitate information processing and routing, the network is divided into subregions. Network traffic flows are determined by the location of regions in which the nodes sense activities of interest. For target tracking and classification applications, the collection, integration, and processing of data takes advantage of the location of active regions to reduce the amount of network traffic. The basic principles of collaborative signal processing for target classification also apply to other distributed decision-making problems in sensor networks.

In "Mobile-Agent-Based Collaborative Signal and Information Processing in Sensor Networks," by Qi *et al.*, the authors concentrate on the target classification aspects of sensor networks. They present an energy-efficient and fault-tolerant approach for collaborative signal and information processing (CSIP) among multiple sensor nodes using a mobile-agent-based computing model. The conflicting

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requirements for energy efficiency and the fault tolerance has always been a challenging issue to the design of CSIP algorithms. The mobile-agent-based collaborative processing strikes a good balance between these two requirements. In this paper, the authors evaluate the performance of different computing paradigms in collaborative processing from both energy consumption and execution time through analytical study and simulation. They claim that mobile-agent-based processing has the great potential to provide an energy-efficient, reliable, and scalable solution for collaborative processing with low latency.

The fourth paper, "Randomized Data Selection in Detection with Applications to Distributed Signal Processing," by Sestok *et al.*, introduces randomized data selection as a technique to cope with limited communication and computation resources in distributed networks. The randomized selection approach may be useful in practical implementations of sensor networks. The paper emphasizes the importance of the randomized selection approach to provide a way to balance the performance criteria with respect to robustness, complexity, and energy efficiency.

The fifth paper, "Collaborative Signal and Information Processing: An Information Directed Approach," contributed by Zhao *et al.*, presents a formulation of sensor network collaborative processing as a distributed constrained optimization. It presents a number of techniques such as IDSQ for distributed tracking problems. By making optimal use of scarce sensing and communication resources, their information-directed approaches are crucial in enabling scalable, multiuser operations of energy-constrained sensor networks.

The next two papers are concerned with the mobility and ad hoc routing aspects of sensor networks. The paper "Efficient Flooding with Passive Clustering—An Overhead-Free Selective Forward Mechanism for Ad Hoc/Sensor Networks," by Kwon *et al.*, presents a passive clustering network for multihop ad hoc routing applications. In this paper, the authors propose a flooding scheme that can reduce the control overhead compared with active clustering schemes. This is achieved by monitoring user data packets that piggyback 2 bits of cluster status information. The paper also provides an overview of the clustering methods using other clustering approaches.

Gharavi and Ban present another paper in this category: "Multihop Sensor Network Design for Wide-Band Communications." The proposed method, which is also based on a cluster-based ad hoc network topology, is designed to provide wide-band access for multimedia applications. The network is based on a new paradigm for solving the problem of cluster-based ad hoc routing when utilizing existing wireless LAN technology. The paper focuses on an assembly of a proof-of-concept development system for testing.

The next treatise, "Distributed Control Applications Within Sensor Networks," by Sinopoli *et al.*, is mainly concerned with designing control systems around sensor networks. The authors, after reviewing useful models of computation, suggest a mixed model for design, analysis, and synthesis of control algorithms within sensor networks. Their modeling choice comes from the analysis of the most common computational models, and proposes a hierarchical structure that is time based at the low level and event based at the coordination level. This is the main thrust and contribution of this paper, a modeling paradigm that can allow the designer to design verifiable control algorithms for sensor-network-based control systems.

The final contribution in our collection is a paper by Chong and Kumar titled "Sensor Networks: Evolution, Opportunities, and Challenges." It presents the evolution of sensor network research over the past three decades, new opportunities due to advances in sensor, computing, and communication technologies, and challenges that must be met to implement sensor networks. This paper traces the history of research in sensor networks over the past three decades, starting with the Distributed Sensor Networks (DSN) program in the 1980s to the recently concluded sensor information technology (SensIT) program, both sponsored by the Defense Advanced Research Projects Agency (DARPA). This paper presents the main technical challenges that must be addressed, including network discovery, control and routing, collaborative signal and information processing, tasking and querying, and security.

The Guest Editors would like to express their deepest gratitude to the reviewers for their time and effort in providing valuable feedback to the authors. They would also like to express their sincere appreciation to the PROCEEDINGS OF THE IEEE editorial board, especially J. Calder, Managing Editor, for the opportunity to put together this special issue.

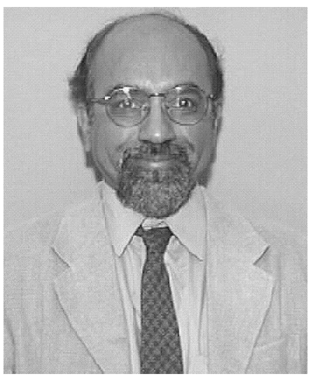
HAMID GHARAVI, *Guest Editor*
Advanced Network
Technology Division
National Institute of Standards
and Technology (NIST)
Gaithersburg, MD

SRIKANTA P. KUMAR, *Guest Editor*
Defense Advanced Research
Projects Agency (DARPA)
Arlington, VA

Hamid Gharavi (Fellow, IEEE) received the Ph.D. degree from Loughborough University, Loughborough, U.K., in 1980.

He joined AT&T Bell Laboratories, Holmdel, NJ, in 1982. He was then transferred to Bell Communications Research (Bellcore) after the AT&T-Bell divestiture, where he became a Consultant on video technology and a Distinguished Member of Research Staff. In 1993, he joined Loughborough University as Professor and Chair of Communication Engineering. Since September 1998, he has been with the National Institute of Standards and Technology (NIST), Gaithersburg, MD. He was a core member of the Study Group XV (Specialist Group on Coding for Visual Telephony) of the International Communications Standardization Body CCITT (ITU-T). He served as a Member of the Communication Sector Panel of the U.K. Technology Foresight Program, Cabinet Office, Office of Science and Technology, from 1994 to 1995. His research interests include video/image transmission, wireless multimedia, mobile communications, ad hoc networks, and third-generation wireless systems. He holds eight U.S. patents related to these topics.

Dr. Gharavi has been an Associate Editor of the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY since 1996 and has been a Guest Editor for a number of special issues in wireless and multimedia communications. He was an Associate Editor of IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS (1987–1989) and served as Chairman of the VLSI Systems and Applications Committee of the IEEE Circuits and Systems (CAS) Society (1989–1991). Currently, he is a member of the Editorial Board of the PROCEEDINGS OF THE IEEE. He received the Charles Babbage Premium Award of the Institute of Electronics and Radio Engineering in 1986 and the IEEE CAS Society Darlington Best Paper Award in 1989.



Srikanta P. Kumar (Senior Member, IEEE) received the B.S. degree (Honors) in physics from Bangalore University, Bangalore, India, in 1971, the B.E. and M.E. degrees from the Indian Institute of Science, Bangalore, in 1974 and 1976, respectively, and the Ph.D. degree in engineering and applied science from Yale University, New Haven, CT, in 1981.

He is currently Program Manager at the Defense Advanced Research Projects Agency (DARPA), and Senior Technical Advisor in the Information Technology Laboratory of the National Institute of Standards and Technology (NIST). At DARPA, he formulated the technical framework for research and technology development for several programs, including the sensor information technology (SensIT) program, the network modeling and simulation (NMS) program, and the bio-computation program. He has been also responsible for the management and execution of these programs. He was a tenured faculty member in the Electrical and Computer Science and Engineering Department, Northwestern University, Evanston, IL, from 1985 to 1998. While at Northwestern, he was the co-founder and founding Director of the Executive Masters Program on Information Technology, an interdisciplinary program involving the McCormick School of Engineering, the Kellogg Business School, and the Communications Department. He served on the faculty of Electrical, Computer, and Systems Engineering Department, Rensselaer Polytechnic Institute, Troy, NY, from 1982 to 1985, and the State University of New York at Buffalo from 1981 to 1982. He has held visiting professor positions at Johns Hopkins University and University of Maryland campuses at College Park and Baltimore County. He has published more than 80 technical papers.