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Editorial

Biao Chen

Department of Electrical Engineering and Computer Science, Syracuse University, Syracuse, NY 13244, USA
Email: bichen@ecs.syr.edu

Wendi B. Heinzelman

Department of Electrical and Computer Engineering, University of Rochester, Rochester, NY 14627, USA
Email: wheinzel@ece.rochester.edu

Mingyan Liu

Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI 48109-2122, USA
Email: mingyan@eecs.umich.edu

Andrew T. Campbell

Department of Electrical Engineering and Center for Telecommunications Research, Columbia University, NY 10027, USA
Email: campbell@comet.columbia.edu

Recent advances in integrated circuits and in digital wireless communication technologies have enabled the design of wireless sensor networks (WSN) to facilitate the joint processing of spatially and temporally distributed information. Such networks immensely enhance our ability to understand and evaluate complex systems and environments. Using wireless connections for sensor networks offers increased flexibility in deployment and reconfiguration of the networks and reduces infrastructure cost. These advantages enable WSN applications in areas ranging from battlefield surveillance to environment monitoring and control to telemedicine.

Enormous challenges in the understanding of sensor networks presently impede deployment of many of the envisaged applications. In particular, for WSN that employ in situ unattended sensors, physical constraints, including those of power, bandwidth, and cost, have presented significant challenges as well as research opportunities in the field. Of particular interest to this special issue are topics related to the communications and networking aspects of WSN. Indeed, one of the major concerns in sensor networks is maintaining connectivity and networking functions with geographically dispersed sensor nodes under stringent resource constraints. This is further exacerbated by the volume of data generated by the sensors, which is disproportionately large compared with the network capacity. The papers in this special issue are reflections of some of these issues.

Sensor networks are typically built to perform some system-wide missions, that is, collective inference tasks that involve all sensor nodes. Examples include detection of an event and estimation of a parameter or a process. The first three papers are concerned with designing such WSN. The first paper, coauthored by Niu and Varshney, considers the detection of an event in sensor networks with a random number of sensors. High network density and limited bandwidth impose a severe constraint on the number of bits each sensor can transmit, and the authors treat the extreme case where a single bit is sent from each sensor. Under the assumption of a Poisson model on the number of sensors, a simple counting rule is proposed at the fusion center to strike a balance between performance and requirement on a priori information. This work demonstrates that for large-scale heterogeneous sensor networks, heuristics based on intuition often trump theoretically optimal processing that is typically too demanding in its requirement. Under the same network architecture, that is, a number of sensors communicating with a single fusion center, the second paper, by Krasnopeev et al. treats an estimation problem where the unknown signal is corrupted by spatially correlated additive noises. Again, bandwidth constraints dictate that each sensor sends a finite number of bits to the fusion center. By exploiting the spatial correlation of the noise in terms of its covariance matrix, the minimum energy quantizer design is reformulated as a convex optimization problem and hence can be solved efficiently using standard convex programming. Taking the problem one step further, the third paper, coauthored by Del Ser et al. deals with the estimation of a random process. Specifically, two binary sources, whose correlation is modeled by a hidden Markov process, are transmitted and the receiver is assumed to reliably recover one of them. This then serves as side information for the decoding of the other. It was demonstrated that the hidden Markov model parameters and the transmitted source can be jointly recovered via iterative decoding.

A perennial problem encountered in large-scale sensor networks is medium access control (MAC): the lack of a central node and the stringent bandwidth and other resource constraints make it an extremely difficult problem. In the paper by Yang et al., the authors consider information retrieval and processing problems in the SENMA (sensor networks with mobile access) network architecture, where data generated by ground sensors are collected by mobile access points (e.g., unmanned aerial vehicles). Three MAC protocols are proposed to produce desired data-retrieval patterns, so as to minimize the reconstruction distortion. These MAC protocols integrate random access by the sensor nodes and the ability of the mobile access points to selectively activate subsets of the sensor field. For a more complicated network model involving multihops, the paper by Cristescu and Servetto describes a solution to the rate control problem at a relay node with partial state information at each source node. The solution reveals an interesting interplay between stability and efficiency; it also provides a distributed medium access control mechanism such that each node can independently decide when it should transmit a packet without complete knowledge of the network state information. Multihop transmission is also considered in the paper by Haapola et al., where an energy dissipation model is proposed to evaluate carrier-sense multiple-access-based MAC protocols. Three different MAC protocols are analyzed with this model and the authors demonstrate how the model can be used to determine when multihop forwarding is more energy-efficient than single-hop transmission in wireless sensor networks.

An important performance measure in sensor networks is the throughput capacity. The paper by Li and Dai considers the tradeoff between throughput and energy efficiency for a reachback channel where multiple sensors send information to an access node. Allowing for an advanced detection scheme at the multiple-antenna receiver, typically feasible for the reachback channel as the access node is not subject to stringent constraints, the authors compare two MAC schemes, round-robin and slotted-Aloha, both in throughput and in energy consumption. It was shown that multiuser scheduling brings significant gain in a fading environment, an observation that corroborates other studies in wireless networks with fading channels. The paper by Liu and Haenggi studies throughput for a multihopped network using slotted-Aloha. It was shown that while a regular network topology exhibits only marginal performance gain over a random topology in terms ofper-link throughput, it does have significant advantages if the end-to-end throughput is of concern.

Finally, Du and Lin discuss in their paper a new node scheduling scheme for heterogeneous sensor networks that provide increased redundancy in certain key areas. Their approach, which utilizes a clustering scheme with high-end cluster head nodes that perform the scheduling of all nodes in their cluster, is energy-efficient by ensuring that only the necessary sensor nodes are turned on to achieve the desired coverage in each cluster.

We would like to thank the individuals who participated in the review process; their dedication has ensured the quality of this special issue and the timeliness of its publication. We also would like to thank the authors who have contributed to this special issue for their effort in abiding to the strict deadlines. We hope that this collection of papers will provide some timely research results and contribute to the literature of this very exciting area.

Biao Chen
Wendi B. Heinzelman
Mingyan Liu
Andrew T. Campbell

Biao Chen received his B.E. and E.E. degrees in electrical engineering from Tsinghua University, Beijing, China, in 1992 and 1994, respectively. From 1994 to 1995, he worked at AT&T (China) Inc., Beijing, China, before he joined the University of Connecticut, Storrs, where he received his M.S. degree in statistics and Ph.D. degree in electrical engineering, in 1998 and 1999, respectively. From 1999 to 2000 he was with Cornell University as a Postdoc Research Associate. Since 2000, he has been with Syracuse University, Syracuse, NY, as an Assistant Professor with the Department of Electrical Engineering and Computer Science. His area of interest mainly focuses on signal processing for wireless sensors and ad hoc networks and on multiuser MIMO systems.

Wendi B. Heinzelman is an Assistant Professor in the Department of Electrical and Computer Engineering at the University of Rochester. She received a B.S. degree in electrical engineering from Cornell University in 1995 and the M.S. and Ph.D. degrees in electrical engineering and computer science from MIT in 1997 and 2000, respectively. Her current research interests lie in the areas of wireless communications and networking, mobile computing, and multimedia communication. She received the NSF CAREER Award in 2005 for her research on cross-layer architectures for wireless sensor networks, and she received the ONR Young Investigator Award in 2005 for her work on balancing resource utilization in wireless sensor networks. She is a Member of Sigma Xi, the IEEE, and the ACM.

Mingyan Liu received her B.S. degree in electrical engineering in 1995 from Nanjing University of Aeronautics and Astronautics, Nanjing, China, the M.S. degree in systems engineering, and the Ph.D. degree in electrical engineering from the University of Maryland, College Park, in 1997 and 2000, respectively. She joined the Department of Electrical Engineering and Computer Science, the University of Michigan, Ann Arbor, in September 2000, where she is currently an Assistant Professor. Her research interests are in performance modeling, analysis, energy-efficiency, and resource allocation issues in wireless mobile ad hoc networks, wireless sensor networks, and terrestrial satellite hybrid networks. She is the recipient of the 2002 NSF CAREER Award and the University of Michigan Elizabeth C. Crosby Research Award in 2003.

Andrew T. Campbell is an Associate Professor of electrical engineering at Columbia University, and a member of the COMET Group. He is working on emerging architectures and programmability for wireless networks. He received his Ph.D. degree in computer science in 1996, and the NSF CAREER Award for his research in programmable mobile networking in 1999. Prior to joining academia he spent 10 years working on transport and operating systems issues in industry. He spent his sabbatical year (2003–2004) at the Computer Lab, Cambridge University, as an EPSRC Visiting Fellow.