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Introduction to the Special Issue on Heterogeneous Wireless Ad Hoc and Sensor Networks

Heterogeneous wireless ad hoc networking covers multi-hop scenarios (network nodes communicating via other network nodes) such as conference, hospital, battlefield, rescue, and monitoring scenarios. They operate in a self-organized and decentralized manner and message communication takes place via multi-hop spreading. Sensor Networks, supported by recent technological advances in low power wireless communications, along with silicon integration of various functionalities such as sensing, communications, intelligence, and actuation are emerging as a critically important disruptive computer class. In ad hoc and sensor networks, communication and computing techniques impact information routing in the network, and vice versa.

This special issue, emphasizes on various aspects of wireless ad hoc and sensor networks and is organized from the papers of the 11th IEEE International Conference on Parallel and Distributed Systems ICPADS, which was held in Fukuoka Institute of Technology, Japan, July 20–22, 2005. The conference received 331 submissions and every paper was reviewed carefully by three reviewers. Based on their quality and significance 118 papers were accepted in ICPADS-2005. We received 31 papers for this special issue. After two more rounds of review, we accepted eight papers based on their quality and suitability to the special issue as well as the journal.

In sensor networks density control is an important technique for prolonging the network's lifetime while providing sufficient sensing coverage. Shang and Shi developed three new density control protocols by considering the tradeoff between energy usage and coverage. The first protocol, Non-Overlapping Density Control, aims at maximizing coverage while avoiding the overlap of sensing areas of active sensors. The second, called Non-Overlapping Density Control Based on Distances, does not require location information of the nodes. And the third one, is a new range-adjustable protocol called Non-Overlapping Density Control for Adjustable Sensing Ranges. It allows heterogeneous sensing ranges for different sensors to save energy consumption. Extensive simulations validate the results of the proposed protocols.

In the second paper, Selvakennedy and Sinnappan proposed the Time-Controlled Clustering Algorithm (TCCA), to realize a network-wide energy reduction. A realistic energy dissipation model is derived probabilistically to quantify the sensor network's energy consumption using the proposed clustering algorithm. A discrete-event simulator is developed to verify the mathematical model and to further investigate TCCA in other scenarios. The simulator is also extended to include the rest of the communication stack to allow a comprehensive evaluation of the proposed algorithm.

In the third paper, Barolli et al. proposed a Genetic Algorithm based routing protocol (GAMAN) for Mobile Ad-hoc Networks (GAMAN). GAMAN is further enhanced by an effective topology extraction algorithm to reduce the search space. The obtained protocol uses two QoS parameters for routing. Simulation results confirm the good performance of the protocol.

In the next paper, Barton et al. study the performance of a technique called *time reversal* for cooperative communication in a mobile wireless environment. The performance of a proposed cooperative *Time Reversal Communication* (TRC) scheme is evaluated numerically

via a simulated indoor environment containing multiple wireless communication nodes. The results demonstrate that the performance of cooperative TRC is less sensitive to uncertainty in target position than might be expected from standard assumptions regarding the relationship between signal wavelength and spatial channel correlation in a complex multipath environment.

In the fifth paper, Taniar and Goh provide a proposal and a case study on how movement pattern can be extracted from mobile users through transforming user movement database to location movement database and subsequently transferred to algorithm Apriori-like movement pattern (*AMP*) and movement tree (*M-tree*). The result is a list of sequences, which satisfies min-support and min-confidence, and that are frequently visited by the mobile users. The result of this movement pattern mining exercise opens up a new future for prediction of movement for the individual mobile user.

In the next paper, Misic and Misic compare the pertinent features of the two emerging technologies for wireless sensor networks: IEEE Standards 802.15.1 and 802.15.4. We review the main features of the MAC protocols defined by those standards, describe their operation, and compare them in terms of characteristics such as performance (access and end-to-end packet delays), bandwidth utilization, and scalability for the deployment of large networks. Their findings indicate that there is no clear winner in all categories; the best protocol (and the underlying technology) to use, are heavily dependent upon the requirements for a particular sensing application. While the main focus of our analysis is the MAC layer, certain important parameters of the Physical (PHY) layer are considered as well, together with some other networking aspects. The results of this analysis should be of interest to the designer and the operators of wireless sensor networks.

Mobile Wireless Ad Hoc Networks are particularly vulnerable due to their fundamental characteristics such as an open medium, dynamic topology, distributed cooperation, and constrained capability. Location information of nodes can be critical in wireless ad hoc networks, especially in those deployed for military purposes. Durresi et al. present two protocols for anonymous routing to prevent location disclosure attacks. The first proposed protocol for Anonymous Routing (PAR) guarantees absolute anonymity, which itself might cause problems as it would become hard to identify malicious and misbehaving nodes. The second protocol, PAR-Enhanced, trades off some anonymity to enable the detection of malicious and misbehaving nodes.

In the last paper, Jones and Atiquzzaman present current and future challenges in the design of transport layers for sensor networks. It is critically important to design an efficient transport layer protocol that combines reliable message delivery and congestion control with minimal overhead and retransmission. In particular, in sensor networks, care must be taken to design and implement transport layer algorithms that allow maximum network lifetime. Current transport layer protocols are compared based on how they implement reliable message delivery, congestion control, and energy efficiency.

We hope that this special issue will lead to a better understanding of issues and protocols related to heterogeneous wireless ad hoc and sensor networks. As we conclude this overview, we would like to thank all the authors for submitting their papers, and a great thanks to all the reviewers for their good work to make it possible to publish this special issue.

In particular, we would like to address our special thanks to the Editor-in-Chief of the International Journal of Distributed Sensor Networks, Prof. Sitharama S. Iyengar, for his strong encouragement and support.

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Guest Editors

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Arjan Durresi received the BE, MS, and Ph.D. (all summa cum laude) all in Electronic-Telecommunications, in 1986, 1991 and 1993, respectively and a Diploma of Superior Specialization in Telecommunications from La Sapienza University in Rome, Italy and Italian Telecommunications Institute in 1991. From 1991 to 1995, he served as a senior software analyst at Telesoft S.p.A, Rome, Italy. From 1995 to 1996, he was a faculty member in the Department of Electronics and Vice Dean of Electrical Faculty at Polytechnic University of Tirana. From 1996 to 2003, he was a research scientist at the Department of Computer and Information Science at Ohio State University. In 2003, he joined Louisiana State University, where he is currently an assistant professor in the Department of Computer Science. His current research interests include network architectures, heterogeneous wireless networks, security, QoS routing protocols, traffic management, optical and satellite networks, multimedia networking, performance testing, and bioinformatics.

Dr. Durresi has published more than forty articles in journals and seventy articles in proceedings of refereed international conference. He is an area editor for the Ad Hoc Networks Journal (Elsevier) and guest editor for the International Journal of Wireless and Mobile Computing and the International Journal of Distributed Sensor Networks. He was Co-Chair and Founder of the First International Workshop in Heterogeneous Wireless Sensor Networks HWISE'2005, Program Co-Chair of AINA2006, Program Vice Chair of AINA2004 and ICPADS 2005, and Program Area Chair of AINA2005. He is the recipient of the Lumley Research Award from the Ohio State University in 2002. He received the appreciation certificate from IEEE Computer Society in 2005. He is a senior member of the IEEE.

Leonard Barolli received the B.E. and Ph.D. degrees from Tirana University and Yamagata University in 1989 and 1997, respectively. From April 1997 to March 1999, he was a JSPS Post Doctor Fellow Researcher at the Department of Electrical and Information Engineering, Yamagata University. From April 1999 to March 2002, he worked as a Research Associate at the Department of Public Policy and Social Studies, Yamagata University. From April 2002 to March 2003, he was an Assistant Professor at the Department of Computer Science, Saitama Institute of Technology (SIT). From April 2003 to March 2005, he was an Associate Professor and presently is a Professor in the Department of Information and Communication Engineering, Fukuoka Institute of Technology (FIT). Dr. Barolli has published more than 100 papers in refereed Journals and International Conference proceedings. He was an Editor of the IPSJ Journal and has served as a Guest Editor for many International Journals. Dr. Barolli has been a PC Member of many International Conferences. He was the PC Chair of IEEE AINA-2004, IEEE ICPADS-2005, MNSA-2005, and NBiS-2005. He is General Co-Chair of IEEE AINA-2006 and MNSA-2006. His research interests include network protocols, Internet applications, wireless networks, agent-based systems, distance learning, network traffic control, fuzzy control, genetic algorithms, sensor networks, and ad-hoc networks. He is a member of SOFT, IPSJ, the IEEE Computer Society, and IEEE. Dr. Barolli has received may research awards and funded research grants. He received the appreciation certificate from the IEEE Computer Society in 2004 and 2005.