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# Introduction to the Special Issue on Advances on Heterogeneous Wireless Sensor Networks

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Heterogeneous Wireless Sensor Networks (HWSN), supported by recent technological advances in low power wireless communications along with silicon integration of various functionalities such as sensing, communications, intelligence, and actuations are emerging as a critically important disruptive computer class based on a new platform, networking structure, and interface that enable novel, low cost, high volume applications such as nuclear, biological, and chemical attack detection and protection, home automation, battlefield surveillance, and environmental monitoring. Several of such applications have been difficult to realize because of problems involved with inputting data from sensors directly into actor systems. To fulfill their large range of applications sensor and actor networks will collaborate with other wired and wireless systems including WLANs, Cellular network, and grid systems. The research community is working to develop high performance computing solutions to problems arising from the complexities of these sensor and actor network systems.

This special issue highlights advances in various aspects of heterogeneous wireless sensor networks and is organized from the papers of the 20th International Conference on Advanced Information Networking and Applications AINA, which was held in Vienna University of Technology, Vienna, Austria, April 18–20, 2006. The conference received 521 submissions and every paper was reviewed carefully by 3 reviewers. Based on their quality and significance 153 papers were accepted in AINA-2006. We received 27 papers for this special issue. After two more rounds of review, we accepted 9 papers based on their quality and suitability to the special issue as well as the journal.

The tradeoff between efficiency and security is very important is sensor networks. Yin and Madria present an Energy Efficient Secure Routing Protocol for Sensor Networks (ESecRout). The protocol uses the symmetric cryptography to secure messages, and uses a small cache in sensor nodes to record the partial routing path (previous and next nodes) to the destination. It guarantees that the destination will be able to identify and discard the tampered

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messages and ensure that the messages received are not tampered. Through simulations it is shown that we show that ESecRouts provides energy efficient secure routing.

In the second paper, Mostarda and Navarra present an approach to provide Intrusion Detection Systems (IDS) facilities into Wireless Sensors Networks (WSN). They derive a new framework that permits to dynamically enforce a set of properties of the sensor's behavior. This is accomplished by an IDS specification that is automatically translated into a few lines of code installed in the sensors.

In the third paper, the authors propose a multi-actuator/multi-sensor model where each sensor sends its information to multiple actuators and each actuator receives sensed information from multiple sensors in an event area. Even if some number of sensors and actuators are faulty, a required action can be performed on actuation devices. Furthermore, the authors discuss how to realize reliable, ordered delivery of sensed information to actuators from sensors on the basis of global time and how to reliably and non-redundantly perform actions.

De Marco and Barolli review a widely accepted transport technique which makes use of the event reliability concept. Authors study the stability of the system by accounting for the irregularities of radio links. They found that indeed the routing protocols should be carefully engineered in order to support event reliability based techniques.

In the next paper Tian, Sheng, and Li present a distributed algorithm (Virtual Grid Spatial Reusing-VGSR) for MAC address assignment. The algorithm is energy efficient and reduces the size of the fixed MAC address. Moreover, VGSR algorithm scales well with the network size and achieves the optimum performance by adjusting the communication range of sensor nodes.

Mišići and Udayshankar consider interconnection of IEEE 802.15.4 beacon enabled network clusters. They discuss two types of interconnections. One type can be achieved by using the PAN coordinator node as the bridging device and the other type is achieved by using ordinary network nodes as bridge nodes. They discuss design and performance issues of both kinds of interconnections.

In the seventh paper, Israr and Awan present a brief survey of various existing clustering algorithms and present a new clustering algorithm based on nondetermistic finite automata which further divides the communication between cluster heads into multihop by using a few nodes from each cluster. Typical experiments demonstrate that the proposed algorithm is more efficient in terms of energy consumption and network connectivity.

The efficiency of the WSN can be improved by in-network data aggregation techniques. This is, however, problematic because the aggregation to be performed depends on the requirements of the end user/application, and is either unknown at the time of deployment or changes over time. Implementation of fixed aggregation algorithms limits the utility of the network. Software-based implementation of dynamic aggregation techniques offers the required flexibility but has significant processing overhead, especially when the size of the network increases. In the eighth paper, Commuri, Tadigotla, and Atiquzzaman propose to reduce the processing overhead by implementing dynamic data aggregation using reconfigurable cluster heads (RCHs) based on Field Programmable Gate Arrays (FPGAs). Such an implementation provides the necessary flexibility in data aggregation techniques demanded by real-time applications, while resulting in significant reduction in the query processing time and the overall power consumption in the network. The objective of the paper is to address the performance improvement in Wireless Sensor Networks (WSNs) through the use of reconfigurable cluster heads. The presented results demonstrate that different data aggregation algorithms can be dynamically and efficiently implemented on the RCHs in run-time.

Designing energy efficient hardware for sensor nodes is the primary goal of the research community. In the last paper, Srivastava and Zhang present the design of a CMOS body-bias generating circuit. The authors show that up to 90% leakage current in CMOS circuits can be reduced by applying the adaptive bias generator to lower threshold voltage CMOS circuits. The design is simple and can be embedded in low power CMOS designs such as the physical nodes of wireless sensor networks.

***Guest Editors***

**Arjan Durresi** received the B.E., M.E.. 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, 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 fifty articles in journals and seventy articles in proceedings of refereed international conferences. 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 is the founder of the IEEE International Workshops on Heterogeneous Wireless Networks - HWISE, and Co-Chair in 2005, 2006, 2007, and 2008. He is the Co-founder of the First International Workshop on Advances in Information Security - WAIS and Co-Chair in 2007 and 2008. He was Co-Chair of AINA2006, Program Vice Chair of AINA2004 and ICPADS 2005. Dr. Durresi is a Yamacraw Distinguished Speaker (2003) and a keynote speaker of IEEE AINA 2007.

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**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-Doctoral 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

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