

ISSN 1726-5479

SENSORS & TRANSDUCERS

3^{vol. 14-2}
Special
/12



Physical and Chemical Sensors & Wireless Sensor Networks

International Frequency Sensor Association Publishing



Editors-in-Chief: Sergey Y. Yurish, tel.: +34 93 413 7941, e-mail: editor@sensorsportal.com

Editors for Western Europe

Meijer, Gerard C.M., Delft University of Technology, The Netherlands
Ferrari, Vittorio, Università di Brescia, Italy

Editor for Eastern Europe

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

Editors for North America

Datskos, Panos G., Oak Ridge National Laboratory, USA
Fabien, J. Josse, Marquette University, USA
Katz, Evgeny, Clarkson University, USA

Editor South America

Costa-Felix, Rodrigo, Inmetro, Brazil

Editor for Africa

Maki K.Habib, American University in Cairo, Egypt

Editor for Asia

Ohyama, Shinji, Tokyo Institute of Technology, Japan

Editor for Asia-Pacific

Mukhopadhyay, Subhas, Massey University, New Zealand

Editorial Advisory Board

- Abdul Rahim, Ruzairi**, Universiti Teknologi, Malaysia
Ahmad, Mohd Noor, Nothern University of Engineering, Malaysia
Annamalai, Karthikeyan, National Institute of Advanced Industrial Science and Technology, Japan
Arcega, Francisco, University of Zaragoza, Spain
Arguel, Philippe, CNRS, France
Ahn, Jae-Pyoung, Korea Institute of Science and Technology, Korea
Arndt, Michael, Robert Bosch GmbH, Germany
Ascoli, Giorgio, George Mason University, USA
Atalay, Selcuk, Inonu University, Turkey
Atghiaee, Ahmad, University of Tehran, Iran
Augutis, Vyngantas, Kaunas University of Technology, Lithuania
Avachit, Patil Lalchand, North Maharashtra University, India
Ayesh, Aladdin, De Montfort University, UK
Azamimi, Azian binti Abdullah, Universiti Malaysia Perlis, Malaysia
Bahreyni, Behraad, University of Manitoba, Canada
Baliga, Shankar, B., General Monitors Transnational, USA
Baoxian, Ye, Zhengzhou University, China
Barford, Lee, Agilent Laboratories, USA
Barlingay, Ravindra, RF Arrays Systems, India
Basu, Sukumar, Jadavpur University, India
Beck, Stephen, University of Sheffield, UK
Ben Bouzid, Sihem, Institut National de Recherche Scientifique, Tunisia
Benachaiba, Chellali, Universitaire de Bechar, Algeria
Binnie, T. David, Napier University, UK
Bischoff, Gerlinde, Inst. Analytical Chemistry, Germany
Bodas, Dhananjay, IMTEK, Germany
Borges Carval, Nuno, Universidade de Aveiro, Portugal
Bouchikhi, Benachir, University Moulay Ismail, Morocco
Bousbia-Salah, Mounir, University of Annaba, Algeria
Bouvet, Marcel, CNRS – UPMC, France
Brudzewski, Kazimierz, Warsaw University of Technology, Poland
Cai, Chenxin, Nanjing Normal University, China
Cai, Qingyun, Hunan University, China
Calvo-Gallego, Jaime, Universidad de Salamanca, Spain
Campanella, Luigi, University La Sapienza, Italy
Carvalho, Vitor, Minho University, Portugal
Cecelja, Franjo, Brunel University, London, UK
Cerda Belmonte, Judith, Imperial College London, UK
Chakrabarty, Chandan Kumar, Universiti Tenaga Nasional, Malaysia
Chakravorty, Dipankar, Association for the Cultivation of Science, India
Changhai, Ru, Harbin Engineering University, China
Chaudhari, Gajanan, Shri Shivaji Science College, India
Chavali, Murthy, N.I. Center for Higher Education, (N.I. University), India
Chen, Jiming, Zhejiang University, China
Chen, Rongshun, National Tsing Hua University, Taiwan
Cheng, Kuo-Sheng, National Cheng Kung University, Taiwan
Chiang, Jeffrey (Cheng-Ta), Industrial Technol. Research Institute, Taiwan
Chiriac, Horia, National Institute of Research and Development, Romania
Chowdhuri, Arijit, University of Delhi, India
Chung, Wen-Yaw, Chung Yuan Christian University, Taiwan
Corres, Jesus, Universidad Publica de Navarra, Spain
Cortes, Camilo A., Universidad Nacional de Colombia, Colombia
Courtois, Christian, Universite de Valenciennes, France
Cusano, Andrea, University of Sannio, Italy
D'Amico, Arnaldo, Università di Tor Vergata, Italy
De Stefano, Luca, Institute for Microelectronics and Microsystem, Italy
Deshmukh, Kiran, Shri Shivaji Mahavidyalaya, Barshi, India
Dickert, Franz L., Vienna University, Austria
Dieguez, Angel, University of Barcelona, Spain
Dighavkar, C. G., M.G. Vidyamandir's L. V.H. College, India
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China
Djordjevich, Alexandar, City University of Hong Kong, Hong Kong
Donato, Nicola, University of Messina, Italy
Donato, Patricio, Universidad de Mar del Plata, Argentina
Dong, Feng, Tianjin University, China
Drljaca, Predrag, Instersema Sensoric SA, Switzerland
Dubey, Venketesh, Bournemouth University, UK
Enderle, Stefan, Univ.of Ulm and KTB Mechatronics GmbH, Germany
Erdem, Gursan K. Arzum, Ege University, Turkey
Erkmen, Aydan M., Middle East Technical University, Turkey
Estelle, Patrice, Insa Rennes, France
Estrada, Horacio, University of North Carolina, USA
Faiz, Adil, INSA Lyon, France
Fericean, Sorin, Balluff GmbH, Germany
Fernandes, Joana M., University of Porto, Portugal
Francioso, Luca, CNR-IMM Institute for Microelectronics and Microsystems, Italy
Francis, Laurent, University Catholique de Louvain, Belgium
Fu, Weiling, South-Western Hospital, Chongqing, China
Gaura, Elena, Coventry University, UK
Geng, Yanfeng, China University of Petroleum, China
Gole, James, Georgia Institute of Technology, USA
Gong, Hao, National University of Singapore, Singapore
Gonzalez de la Rosa, Juan Jose, University of Cadiz, Spain
Granell, Annette, Goteborg University, Sweden
Graff, Mason, The University of Texas at Arlington, USA
Guan, Shan, Eastman Kodak, USA
Guillet, Bruno, University of Caen, France
Guo, Zhen, New Jersey Institute of Technology, USA
Gupta, Narendra Kumar, Napier University, UK
Hadjiloucas, Sillas, The University of Reading, UK
Haider, Mohammad R., Sonoma State University, USA
Hashsham, Syed, Michigan State University, USA
Hasni, Abdelhafid, Bechar University, Algeria
Hernandez, Alvaro, University of Alcalá, Spain
Hernandez, Wilmar, Universidad Politecnica de Madrid, Spain
Homentcovschi, Dorel, SUNY Binghamton, USA
Horstman, Tom, U.S. Automation Group, LLC, USA
Hsiai, Tzung (John), University of Southern California, USA
Huang, Jeng-Sheng, Chung Yuan Christian University, Taiwan
Huang, Star, National Tsing Hua University, Taiwan
Huang, Wei, PSG Design Center, USA
Hui, David, University of New Orleans, USA
Jaffrezic-Renault, Nicole, Ecole Centrale de Lyon, France
James, Daniel, Griffith University, Australia
Janting, Jakob, DELTA Danish Electronics, Denmark
Jiang, Liudi, University of Southampton, UK
Jiang, Wei, University of Virginia, USA
Jiao, Zheng, Shanghai University, China
John, Joachim, IMEC, Belgium
Kalach, Andrew, Voronezh Institute of Ministry of Interior, Russia
Kang, Moonho, Sunmoon University, Korea South
Kaniasus, Eugenijus, Vienna University of Technology, Austria
Katake, Anup, Texas A&M University, USA
Kausel, Wilfried, University of Music, Vienna, Austria
Kavasoglu, Nese, Mugla University, Turkey
Ke, Cathy, Tyndall National Institute, Ireland
Khelfaoui, Rachid, Université de Bechar, Algeria
Khan, Asif, Aligarh Muslim University, Aligarh, India
Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics. and Telecom. Research Inst., Korea South
Kotulska, Malgorzata, Wroclaw University of Technology, Poland
Kockar, Hakan, Balikesir University, Turkey

Kong, Ing, RMIT University, Australia
Kratz, Henrik, Uppsala University, Sweden
Krishnamoorthy, Ganesh, University of Texas at Austin, USA
Kumar, Arun, University of Delaware, Newark, USA
Kumar, Subodh, National Physical Laboratory, India
Kung, Chih-Hsien, Chang-Jung Christian University, Taiwan
Lacnjevac, Caslav, University of Belgrade, Serbia
Lay-Ekuakille, Aime, University of Lecce, Italy
Lee, Jang Myung, Pusan National University, Korea South
Lee, Jun Su, Amkor Technology, Inc. South Korea
Lei, Hua, National Starch and Chemical Company, USA
Li, Fengyuan (Thomas), Purdue University, USA
Li, Genxi, Nanjing University, China
Li, Hui, Shanghai Jiaotong University, China
Li, Xian-Fang, Central South University, China
Li, Yuefa, Wayne State University, USA
Liang, Yuanchang, University of Washington, USA
Liawruangrath, Saisunee, Chiang Mai University, Thailand
Liew, Kim Meow, City University of Hong Kong, Hong Kong
Lin, Hermann, National Kaohsiung University, Taiwan
Lin, Paul, Cleveland State University, USA
Linderholm, Pontus, EPFL - Microsystems Laboratory, Switzerland
Liu, Aihua, University of Oklahoma, USA
Liu Changgeng, Louisiana State University, USA
Liu, Cheng-Hsien, National Tsing Hua University, Taiwan
Liu, Songqin, Southeast University, China
Lodeiro, Carlos, University of Vigo, Spain
Lorenzo, Maria Encarnacio, Universidad Autonoma de Madrid, Spain
Lukaszewicz, Jerzy Pawel, Nicholas Copernicus University, Poland
Ma, Zhanfang, Northeast Normal University, China
Majstorovic, Vidosav, University of Belgrade, Serbia
Malyshev, V.V., National Research Centre 'Kurchatov Institute', Russia
Marquez, Alfredo, Centro de Investigacion en Materiales Avanzados, Mexico
Matay, Ladislav, Slovak Academy of Sciences, Slovakia
Mathur, Prafull, National Physical Laboratory, India
Maurya, D.K., Institute of Materials Research and Engineering, Singapore
Mekid, Samir, University of Manchester, UK
Melnyk, Ivan, Photon Control Inc., Canada
Mendes, Paulo, University of Minho, Portugal
Mennell, Julie, Northumbria University, UK
Mi, Bin, Boston Scientific Corporation, USA
Minas, Graca, University of Minho, Portugal
Moghavvemi, Mahmoud, University of Malaya, Malaysia
Mohammadi, Mohammad-Reza, University of Cambridge, UK
Molina Flores, Esteban, Benemerita Universidad Autónoma de Puebla, Mexico
Moradi, Majid, University of Kerman, Iran
Morello, Rosario, University "Mediterranea" of Reggio Calabria, Italy
Mounir, Ben Ali, University of Sousse, Tunisia
Mrad, Nezih, Defence R&D, Canada
Mulla, Imtiaz Sirajuddin, National Chemical Laboratory, Pune, India
Nabok, Aleksey, Sheffield Hallam University, UK
Neelamegam, Periasamy, Sastra Deemed University, India
Neshkova, Milka, Bulgarian Academy of Sciences, Bulgaria
Oberhammer, Joachim, Royal Institute of Technology, Sweden
Ould Lahoucine, Cherif, University of Guelma, Algeria
Pamidighanta, Sayanu, Bharat Electronics Limited (BEL), India
Pan, Jisheng, Institute of Materials Research & Engineering, Singapore
Park, Joon-Shik, Korea Electronics Technology Institute, Korea South
Penza, Michele, ENEA C.R., Italy
Pereira, Jose Miguel, Instituto Politecnico de Seteбал, Portugal
Petsev, Dimiter, University of New Mexico, USA
Pogacnik, Lea, University of Ljubljana, Slovenia
Post, Michael, National Research Council, Canada
Prance, Robert, University of Sussex, UK
Prasad, Ambika, Gulbarga University, India
Prateepasen, Asa, Kingmoungut's University of Technology, Thailand
Pugno, Nicola M., Politecnico di Torino, Italy
Pullini, Daniele, Centro Ricerche FIAT, Italy
Pumera, Martin, National Institute for Materials Science, Japan
Radhakrishnan, S., National Chemical Laboratory, Pune, India
Rajanna, K., Indian Institute of Science, India
Ramadan, Qasem, Institute of Microelectronics, Singapore
Rao, Basuthkar, Tata Inst. of Fundamental Research, India
Raouf, Kosai, Joseph Fourier University of Grenoble, France
Rastogi Shiva, K., University of Idaho, USA
Reig, Candid, University of Valencia, Spain
Restivo, Maria Teresa, University of Porto, Portugal
Robert, Michel, University Henri Poincare, France
Rezazadeh, Ghader, Urmia University, Iran
Royo, Santiago, Universitat Politecnica de Catalunya, Spain
Rodriguez, Angel, Universidad Politecnica de Cataluna, Spain
Rothberg, Steve, Loughborough University, UK
Sadana, Ajit, University of Mississippi, USA
Sadeghian Marnani, Hamed, TU Delft, The Netherlands
Sapozhnikova, Ksenia, D.I.Mendeleyev Institute for Metrology, Russia
Sandacci, Serghei, Sensor Technology Ltd., UK
Saxena, Vibha, Bbhba Atomic Research Centre, Mumbai, India
Schneider, John K., Ultra-Scan Corporation, USA
Sengupta, Deepak, Advance Bio-Photonics, India
Seif, Selemeni, Alabama A & M University, USA
Seifter, Achim, Los Alamos National Laboratory, USA
Shah, Kriyang, La Trobe University, Australia
Sankarraj, Anand, Detector Electronics Corp., USA
Silva Girao, Pedro, Technical University of Lisbon, Portugal
Singh, V. R., National Physical Laboratory, India
Slomovitz, Daniel, UTE, Uruguay
Smith, Martin, Open University, UK
Soleymanpour, Ahmad, Damghan Basic Science University, Iran
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Sridharan, M., Sastra University, India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., NanoSonix Inc., USA
Stefan-van Staden, Raluca-Ioana, University of Pretoria, South Africa
Stefanescu, Dan Mihai, Romanian Measurement Society, Romania
Sumriddetchka, Sarun, National Electronics and Computer Technology Center, Thailand
Sun, Chengliang, Polytechnic University, Hong-Kong
Sun, Dongming, Jilin University, China
Sun, Junhua, Beijing University of Aeronautics and Astronautics, China
Sun, Zhiqing, Central South University, China
Suri, C. Raman, Institute of Microbial Technology, India
Sysoev, Victor, Saratov State Technical University, Russia
Szewczyk, Roman, Industrial Research Inst. for Automation and Measurement, Poland
Tan, Ooi Kiang, Nanyang Technological University, Singapore
Tang, Dianping, Southwest University, China
Tang, Jaw-Luen, National Chung Cheng University, Taiwan
Teker, Kasif, Frostburg State University, USA
Thirunavukkarasu, I., Manipal University Karnataka, India
Thumavanam Pad, Kartik, Carnegie Mellon University, USA
Tian, Gui Yun, University of Newcastle, UK
Tsiantos, Vassilios, Technological Educational Institute of Kaval, Greece
Tsigara, Anna, National Hellenic Research Foundation, Greece
Twomey, Karen, University College Cork, Ireland
Valente, Antonio, University, Vila Real, - U.T.A.D., Portugal
Vanga, Raghav Rao, Summit Technology Services, Inc., USA
Vaseashta, Ashok, Marshall University, USA
Vazquez, Carmen, Carlos III University in Madrid, Spain
Vieira, Manuela, Instituto Superior de Engenharia de Lisboa, Portugal
Vigna, Benedetto, STMicroelectronics, Italy
Yrba, Radimir, Brno University of Technology, Czech Republic
Wandelt, Barbara, Technical University of Lodz, Poland
Wang, Jiangping, Xi'an Shiyou University, China
Wang, Kedong, Beihang University, China
Wang, Liang, Pacific Northwest National Laboratory, USA
Wang, Mi, University of Leeds, UK
Wang, Shinn-Fwu, Ching Yun University, Taiwan
Wang, Wei-Chih, University of Washington, USA
Wang, Wensheng, University of Pennsylvania, USA
Watson, Steven, Center for NanoSpace Technologies Inc., USA
Weiping, Yan, Dalian University of Technology, China
Wells, Stephen, Southern Company Services, USA
Wolkenberg, Andrzej, Institute of Electron Technology, Poland
Woods, R. Clive, Louisiana State University, USA
Wu, DerHo, National Pingtung Univ. of Science and Technology, Taiwan
Wu, Zhaoyang, Hunan University, China
Xiu Tao, Ge, Chuzhou University, China
Xu, Lisheng, The Chinese University of Hong Kong, Hong Kong
Xu, Sen, Drexel University, USA
Xu, Tao, University of California, Irvine, USA
Yang, Dongfang, National Research Council, Canada
Yang, Shuang-Hua, Loughborough University, UK
Yang, Wuqiang, The University of Manchester, UK
Yang, Xiaoling, University of Georgia, Athens, GA, USA
Yaping Dan, Harvard University, USA
Ymeti, Aurel, University of Twente, Netherland
Yong Zhao, Northeastern University, China
Yu, Haihu, Wuhan University of Technology, China
Yuan, Yong, Massey University, New Zealand
Yufera Garcia, Alberto, Seville University, Spain
Zakaria, Zulkarnay, University Malaysia Perlis, Malaysia
Zagnoni, Michele, University of Southampton, UK
Zamani, Cyrus, Universitat de Barcelona, Spain
Zeni, Luigi, Second University of Naples, Italy
Zhang, Minglong, Shanghai University, China
Zhang, Qintao, University of California at Berkeley, USA
Zhang, Weiping, Shanghai Jiao Tong University, China
Zhang, Wenming, Shanghai Jiao Tong University, China
Zhang, Xueji, World Precision Instruments, Inc., USA
Zhong, Haoxiang, Henan Normal University, China
Zhu, Qing, Fujifilm Dimatix, Inc., USA
Zorzano, Luis, Universidad de La Rioja, Spain
Zourob, Mohammed, University of Cambridge, UK

Contents

Volume 14-2
Special Issue
March 2012

www.sensorsportal.com

ISSN 1726-5479

Research Articles

Information Extraction from Wireless Sensor Networks: System and Approaches <i>Tariq Alsboui, Abdelrahman Abuarqoub, Mohammad Hammoudeh, Zuhair Bandar, Andy Nisbet...</i>	1
Assessment of Software Modeling Techniques for Wireless Sensor Networks: A Survey <i>John Khalil Jacoub, Ramiro Liscano, Jeremy S. Bradbury</i>	18
Effective Management and Energy Efficiency in Management of Very Large Scale Sensor Network <i>Moran Feldman, Sharoni Feldman</i>	47
Energy Efficient in-Sensor Data Cleaning for Mining Frequent Itemsets <i>Jacques M. Bahi, Abdallah Makhoul, Maguy Medlej</i>	64
IPv6 Routing Protocol for Low Power and Lossy Sensor Networks Simulation Studies <i>Leila Ben Saad, Cedric Chauvenet, Bernard Tourancheau</i>	79
Self-Powered Intelligent Sensor Node Concept for Monitoring of Road and Traffic Conditions <i>Sebastian Strache, Ralf Wunderlich and Stefan Heinen</i>	93
Variable Step Size LMS Algorithm for Data Prediction in Wireless Sensor Networks <i>Biljana Risteska Stojkoska, Dimitar Solev, Danco Davcev</i>	111
A Framework for Secure Data Delivery in Wireless Sensor Networks <i>Leonidas Perlepes, Alexandros Zaharis, George Stamoulis and Panagiotis Kikiras</i>	125
An Approach for Designing and Implementing Middleware in Wireless Sensor Networks <i>Ronald Beaubrun, Jhon-Fredy Llano-Ruiz, Alejandro Quintero</i>	150
Mobility Model for Self-Organizing and Cooperative MSN and MANET Systems <i>Andrzej Sikora and Ewa Niewiadomska-Szynkiewicz</i>	164
Evaluation of Hybrid Distributed Least Squares for Improved Localization via Algorithm Fusion in Wireless Sensor Networks <i>Ralf Behnke, Jakob Salzmann, Philipp Gorski, Dirk Timmermann</i>	179
An Effective Approach for Handling both Open and Closed Voids in Wireless Sensor Networks <i>Mohamed Aissani, Sofiane Bouznad, Abdelmalek Hariza and Salah-Eddine Allia</i>	196
Embedded Wireless System for Pedestrian Localization in Indoor Environments <i>Nicolas Fourty, Yoann Charlon, Eric Campo</i>	211
Neighbourtables – A Cross-layer Solution for Wireless CiNet Network Analysis and Diagnostics <i>Ismo Hakala and Timo Hongell</i>	228

A Column Generation based Heuristic to extend Lifetime in Wireless Sensor Network <i>Karine Deschinkel</i>	242
Adapting OLSR for WSNs (iOLSR) Using Locally Increasing Intervals <i>Erlend Larsen, Joakim Flathagen, Vinh Pham, Lars Landmark</i>	254
Risk Assessment along Supply Chain: A RFID and Wireless Sensor Network Integration Approach <i>Laurent Gomez, Maryline Laurent, Ethmane El Moustaine</i>	269
Structure Crack Identification Based on Surface-mounted Active Sensor Network with Time-Domain Feature Extraction and Neural Network <i>Chunling Du, Jianqiang Mou, L. Martua, Shudong Liu, Bingjin Chen, Jingliang Zhang, F. L. Lewis.</i>	283
Efficient Gatherings in Wireless Sensor Networks Using Distributed Computation of Connected Dominating Sets <i>Vincent Boudet, Sylvain Durand, László Gönczy, Jérôme Mathieu and Jérôme Palaysi</i>	297
Secure Packet Transfer in Wireless Sensor Networks <i>Yenumula B. Reddy</i>	308

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm>

International Frequency Sensor Association (IFSA).

IMAGE SENSORS 2012
TWO DAY INTERTECHPIRA CONFERENCE PLUS EXPERT PRE-CONFERENCE WORKSHOPS
FOCUS ON DIGITAL IMAGING

PRESENTATIONS FROM:

- SoftKinetic
- BBC
- NASA
- NHS
- Leica Geosystems
- Sony Ericsson
- OLYMPUS
- Panasonic Ideas for life
- SIEMENS
- raytrix
- BOSCH
- Leti
- SAFRAN
- caeleste
- PELCO
- SONY
- Aptina
- NMK

SUPPORTING PARTNERS:

- Plastic
- IFSA
- 3D Packaging
- imaging and machine vision
- Micronews
- cmva

REGISTER NOW IMAGE-SENSORS.COM

OVERVIEW [WHY ATTEND](#) [TUES 20 MAR](#) [WED 21 MAR](#) [THURS 22 MAR](#) [VENUE](#)

IMAGE SENSORS 2012
20-22 March
Hotel Russell
London

IS 2012

The 6th International Conference on Sensor Technologies and Applications



SENSORCOMM 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012



Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks

<http://www.aria.org/conferences2012/SENSORCOMM12.html>

The 3rd International Conference on Sensor Device Technologies and Applications



SENSORDEVICES 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012



Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Geosensors - Sensor device technologies - Sensors signal conditioning and interfacing circuits - Medical devices and sensors applications - Sensors domain-oriented devices, technologies, and applications - Sensor-based localization and tracking technologies

<http://www.aria.org/conferences2012/SENSORDEVICES12.html>

The 5th International Conference on Advances in Circuits, Electronics and Micro-electronics



CENICS 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012



Tracks: Semiconductors and applications - Design, models and languages - Signal processing circuits - Arithmetic computational circuits - Microelectronics - Electronics technologies - Special circuits - Consumer electronics - Application-oriented electronics

<http://www.aria.org/conferences2012/CENICS12.html>

Neighbourtables – A Cross-layer Solution for Wireless CiNet Network Analysis and Diagnostics

Ismo HAKALA and Timo HONGELL

University of Jyväskylä, Kokkola University Consortium Chydenius

Talonpojankatu 2B, 67100, Finland

Tel.: +358 68294285, fax: +358 68294202,

E-mail: ismo.hakala@chydenius.fi, timo.hongell@chydenius.fi

Received: 15 November 2011 /Accepted: 20 December 2011 /Published: 12 March 2012

Abstract: For successful deployment of a wireless sensor network, reliable communication between the networks' nodes is crucial. When communication and other wireless sensor networks constraints are taken into account, networks can be analyzed efficiently. The diagnosis of the network's operation can be done using the information gathered by the sensor nodes in the network. This paper discusses wireless sensor network diagnostics, describes so-called neighbourtables used to collect diagnostic data of the wireless CiNet network and the construction of them using the synchronization and management messages. The neighbourtables are embedded to the CiNet network cross-layer architecture and this solution results to relatively small energy overhead consumption caused by them. The information stored in neighbourtables can be used to monitor network behavior and to improve networks' packet routing and fault recognizing for the nodes, in both, nodes' and centralized applications' point of view. *Copyright © 2012 IFSA.*

Keywords: Neighbourtables, Wireless sensor network, Diagnostic, Management.

1. Introduction

In recent years, study of wireless sensor networks (WSN) has become a rapidly developing research area. A WSN is a set of wireless sensor nodes where each node measures a physical value using selected sensor probes and sends the value to a database through specific sink nodes. Nowadays, WSNs are widely used in civil and industrial applications such as smart home or environment monitoring [1-3]. Compared to traditional sensing methods, wireless sensor networks technology offers some benefits: wide areas can be covered with inexpensive, energy-efficient battery-powered

devices, which make long-term monitoring and real time access to measuring data possible. Often the nodes of WSN also are able to self-configure themselves, which enables quick and easy system deployment.

The use of WSN-applications also reveals many different constraints that can decrease the possible number of real application deployments. These constraints may be defined in different categories based on the constraints type, such as the system's memory, processors' limitations and energy consumption. Out-of-date communication equipment and their bandwidth as well as physical environmental and measurement factors related to sensors' location and calibration also may be the cause of different constraints.

A WSN can take into account some of the possible constraints by gathering diagnostic information from the network. For example, radio link quality is affected by many internal and external factors, and it can be evaluated by using the Received Signal Strength Indicator (RSSI). RSSI values as well as other diagnostic data, such as battery levels, the number of received packets etc., can be stored in one table, the so-called neighbourtable.

In CiNet WSN nodes, the diagnostic data is collected during the synchronization process to the node's neighbourtables that are embedded to be a part of the cross-layer architecture. The use of a cross-layer implementation reduces computational and memory requirements, since not all the information needs to be transmitted between application interfaces and protocol layers. The neighbourtables gives the nodes direct information about the network around them and also information about the sink node. The node can directly use the neighbourtable information to determine its routing and clustering possibilities based on the collected and calculated information about the neighbour nodes. Since the nodes' neighbourtables can be centrally collected to a server database, they can be utilized in different diagnostic applications. For example, we have developed a graphical real time application, CiNetView, to make wireless sensor network deployment and monitoring more reliable. The application visualizes, in real time, the nodes' relative locations as well as shows the links' quality, which make the deployment of WSN much quicker and easier.

This journal paper is an extended version of [4] and discusses reasons for wireless sensor network diagnostics and describes the so-called neighbourtables used in the wireless CiNet sensor network. The paper is organized as follows: First, we provide a brief description of some related research and discuss the useful diagnostic data and neighbourtables in WSN. Section 3 presents the neighbourtables construction in CiNet network as a part of the cross-layer entity as well as their usage. The construction is defined to be a part of the synchronization protocol. Other functionalities of the tables are also described in more detail. In Section 4 survey of the neighbourtables' energy cost is presented. Finally, some experiences of the use of neighbourtables in real wireless sensor network implementations are discussed and acknowledgements are given.

2. Network Management Issues

Analysis and monitoring of WSNs are highly evolving research topics in the field of wireless technology. However, real time performance of wireless communication is not that widely studied. In [5], Meier et al. discuss link behavior and metrics that can be used to evaluate link performance. They have used statistical link analysis in their studies. Ferrari et al. have done indoor performance studies of WSNs [6]. Sensor network diagnostics and visualization are discussed in [3]. However, there has not been much discussion on real time inspections of the changes in link qualities, whether uplink or downlink, in sensor networks or the architectures of the used diagnostic solutions.

For a customer's point of view, wireless network is fine when the wanted information is received and processed correctly, that is, when the network works properly. On the other hand, wireless networks include many different information pieces that can be used to give useful information about the networks' operational performance and reliability, not only for the user or customer, but also for the networks' maintenance crew as well. Sensor nodes' small dimension causes restrictions on its resources such as battery, memory, processing capability, used radio and communication standards etc. These consequently limit sensor nodes to perform large calculation tasks. Due to the limited amount of memory and space in the sensor nodes and the transmitted data frames, it is reasonable to define the relevant information and metrics that can be used in WSN diagnostics. Fynn [7] has done a collective study of WSN performance analysis methods and metrics, the topics including storage, routing, real time communication, power management and architecture. Jacuot et al. have discussed indirect diagnosis of the node state with few messages, using an SNMP-like LiveNCM management tool [8].

The main idea of WSN diagnosing and monitoring is to gather information about the relevant network parameters, which include: node states (battery level and transmitting power), network topology (the known neighbours of the nodes), link states (connection status of the nodes), and the topographical coverage of the WSN. A typical sensor network diagnostic and management system can perform different numbers of management control tasks based on the collected information about the network states. Some management tasks can include the remote controlling of the nodes, switching node on/off (power management), controlling the routing decisions (packet routing management), and performing network reconfiguration in order to recover from node and communication faults. In an ideal management case these operations are embedded to the system and they are performed automatically by the management software or some other management tool. There are some commercial network visualization and diagnostic applications, for example, MOTE-VIEW [9] and Surge View [10], developed by Crossbow Technology.

Wireless sensor nodes are typically not deployed in optimal conditions and therefore the configuration of nodes in WSNs may change dynamically. Thus, a sensor network management system should allow the network to be able to self-configure in the event of failures without prior knowledge of the network topology. Typically, most of the sensor network applications are designed in a way that they support network management, therefore no extra network management layer is needed.

In general the most important information from the node's point of view in every communicating network are its neighbours' addresses, since without them other information cannot be linked to a specific node and it is almost impossible to perform any data routing in through the network. Depending on the used systems and network solutions the node addresses can be defined differently, but the overall goal is to be able to identify each of the nodes unambiguously.

In a typical WSN the sink node is defined to be the so-called root of the network, and its relative location need also be known. Therefore, a metric called hop count is essential information for the nodes. The bigger the hop count the greater the number of relaying nodes that are needed for sending packets between the specific sensor node and the sink node. This value does not necessarily directly indicate the physical distance, but rather the relative length of a path that a data packet needs to be forwarded to reach the sink node. Additionally the hop count value tells the node the direction of the sink that the packet is to be sent to with the minimum number of forwarding retransmissions. Hop count values can also be defined to be calculated from the nearest gateway of the node.

Radio link quality is affected by many factors, which can be divided into a device's internal and external factors. The internal factors are caused by imperfections of the device's hardware or software. E.g., different radio chips do not behave exactly in the same way and each node has its own radiation pattern that is not uniform [2]. The external factors, such as fading, shadowing, multipath propagation,

and dynamic environmental factors affect wireless communication and make it difficult to predict the radio performance beforehand. Link quality can be evaluated by using the Received Signal Strength Indicator (RSSI), which indicates the strength of the radio signal between two nodes at the receiver's position.

When sent packages are spread from the sink node to the last node in the network, it is possible that some of the packages arrive through multiple paths and are somewhat delayed. Nodes need to be able to recognize the packets that have been sent on the same synchronization period. Therefore, every packet has its own sequence number, which also needs to be stored. Some of the packets may be received from different neighbour nodes, meaning that the packets have traveled through different paths from sink to the receiver node. Packet routing is also one interesting network management related topic that will be discussed later. Routing using neighbourtables is studied in [11] and [12].

In a wireless sensor network nodes naturally need energy to operate, and they usually are battery powered. The lifetime of a sensor node is mainly determined by the power supply since battery replacement is not typically an option in sensor networks, especially in environmental monitoring cases. The varying shape and utilization of the network cause that the battery levels of the nodes do not consume at the same rate all over the network. The longer the lifetime of a sensor, the more stable the WSN. Therefore, it is essential to know that how much the batteries have power left.

In addition to these considerations, the nodes can be programmed to have several different counters that can be set to count, for example, the number of received and missed packets. These counters can then be used to calculate, e.g., throughput and reliability values of the sensor or relay nodes. All the introduced information can be used on its own or together as a combination to enhance different management and diagnostic operations in the network deployment and monitoring phases, such as topology control and packet routing. But before these information pieces can be utilized, all the information needs to be stored somewhere. One solution is to use neighbourtables that are embedded in the management entity of the used cross-layer architecture. The solution allows all the protocol layers to utilize same information, which reduces space needed.

Typically, when talking about neighbourtables, the topic equates to a conventional routing tables. A short comparison of neighbourtables and routing tables is needed. A routing table is a set of rules that is used to decide where data packets traveling over network will be directed. Each packet contains information about its origin and destination. The routing table contains the information necessary to forward a packet along the best path toward its destination. Usually a routing table includes the following information:

- Destination: The address of the packet's final destination;
- Next hop: The address to which the packet is to be forwarded;
- Metric: Assigns a cost to each available route so that the most cost-effective path can be chosen.

Our definition of neighbourtable is that neighbourtables basically include, not only the same information as routing tables, but also some additional information. They can be used to aid routing decisions, but they can also be used in different diagnostic and management solutions as well. For a single node's point of view, a neighbourtable is a multifunctional set of information about the nodes' neighbour nodes and the links between them. Globally speaking, the neighbourtable file, constructed by the server, includes all essential information about the whole network, and the whole network's operation can be diagnosed and monitored in real time from there. One approach that uses additional messages to construct and utilize neighbourtables is considered in [13].

3. The CiNet Neighbourtable

We are using CiNet nodes [2, 14] in our study. CiNet is a research and development platform for the WSN implemented in Kokkola University Consortium Chydenius. The CiNet platform is specially designed for WSNs and consists of inexpensive, standard off-the-shelf components. There exist two different versions of the platform. Each version uses different IEEE802.15.4 radio modules, but the system architecture is common. All 2.4 GHz versions can work seamlessly in the same network. The CiNet node includes all the basic components necessary for WSNs. The CiNet nodes are also ported to Jennic radio module [15] and ZigBit module with ATmega1281/AT86RF212 radios [16]. Neighbourtable usage is also implemented to these modules and the research work is ongoing. The system architecture of a typical wireless sensor network application using the CiNet network is displayed in Fig. 1. In our CiNet network, the nodes use cross-layer architecture [14].

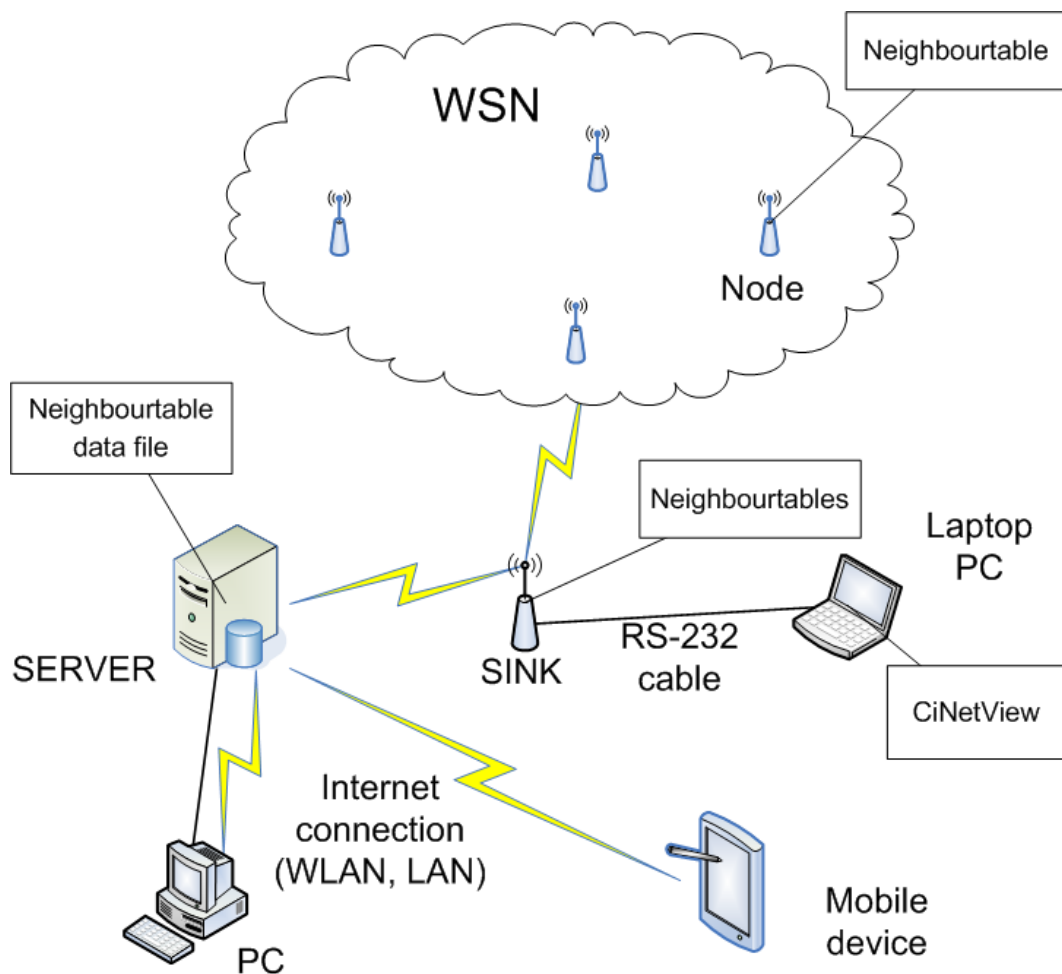


Fig. 1. The system structure of CiNet network.

The main idea of the cross-layer architecture is to implement a wireless sensor network's basic tasks, such as topology management and power saving functionalities, as separate protocols in a cross-layer management entity. Data structures, which are in common use, are in this study implemented in the cross-layer management entity as a neighbourtable data addition. The use of a cross-layer implementation reduces computational and memory requirements - not all the information needs to be transmitted between application interfaces and protocol layers. The architecture also allows the implementation of the application and protocol stacks be as simple as possible, since they are practically free of the tasks related to network management.

In every node, the neighbourtable is stored to one common data storage in the cross-layer management entity, where all the protocol stack layers can utilize the same information, see Fig. 2. This reduces the total amount of memory storage space needed, but the use of cross-layer architecture causes challenges related to maintenance, which have to be considered in the implementation. The problem has been approached by using message multiplexing in the data link layer and modular structure in the cross-layer management entity.

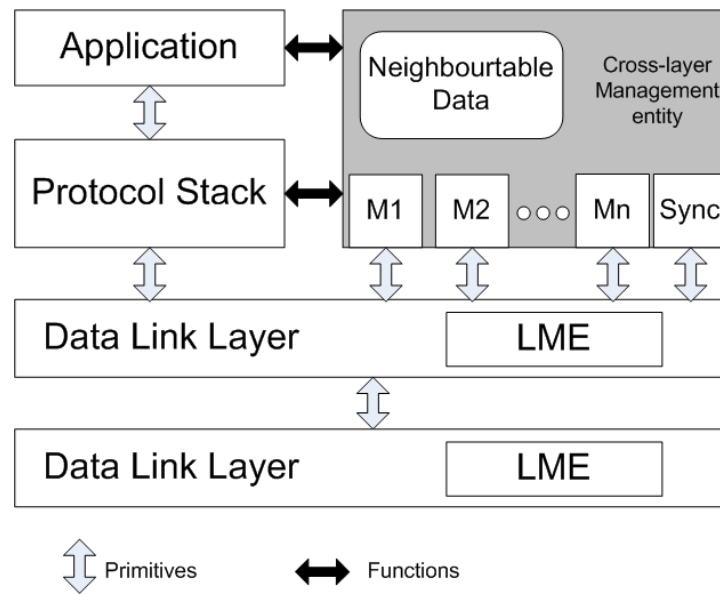


Fig. 2. CiNet network's cross-layer architecture.

Basically the neighbourtable of each node consists of d levels with b entries at each level. More precisely, every level d is a different neighbour of the node and each entry b includes stored information, such as node ID, battery level, RSSI and hop count.

All the nodes' neighbourtables are also collected to a single data file on a server, from where all the information can be retrieved. This centralized neighbourtable can be used in different WSN management and diagnostic applications and tools. The format of the file is shown in Table 1.

Table 1. Format of the server's neighbourtable data file.

Seq No	Node ID 1	Neighbour 1 data	Neighbour 2 data	...
Seq No	Node ID 2	Neighbour 1 data	Neighbour 2 data	...
⋮	⋮	⋮	⋮	⋮
Seq No	Node ID N	Neighbour 1 data	Neighbour 2 data	...

3.1. Neighbourtable Construction

In a CiNet network, each node constructs and maintains its own neighbourtable, as defined in Table 2, in which the node stores information about its neighbours, which are the nodes that it hears. The neighbourtable of each node is updated in every synchronization period of the network, see Fig. 3. The neighbourtable construction and update is defined to be one part of the synchronization protocol. The sink node broadcasts the synchronization message isotropically, and every node that hears it broadcasts

that message onwards through the network during a predefined time period. In this way the whole network can be synchronized. The synchronization frame structure is shown in Fig. 4(a). The SYNC frame also includes additional data that is not used in the neighbourtables, such as the CMD and a command byte that can be used to control the nodes' operation. Before relaying the synchronization message, the nodes update it with their own information. Based on the received synchronization messages and the data included in the synchronization frames, the nodes update their neighbourtables. Note that the synchronization messages are heard by all the nodes' neighbours, including the predecessors, which means that the neighbourtable information can be collected in both directions. To prevent any ping-pong effect, the nodes broadcast the synchronization message only once in every synchronization period. Continuous synchronization of the network is vital to ensure valid operation of the network.

Table 2. CiNet nodes' neighbourtable.

U16INT u16NbAddr	Neighbor address
S8INT s8RSSI	Neighbor link RSSI value
U8INT u4Bat:4	Battery level of the neighbor
U8INT u4HopCnt:4	Hop count of the neighbour
U8INT u8NodeType	Sink, Relay, Sensor
U16INT u16Received	Number of received sync packets
U16INT u16Missed	Number of missed sync packets
S8INT s8AvgRSSI	Average RSSI of the neighbour link
S8INT s8PathRSSI	Path RSSI (path's weakest RSSI)
U8INT u8PrevSeq	Previous sequence number
U8INT u8Ntp	UpLink throughput
U8INT u8UplinkTp	Path throughput
U32INT u32NbLastSeen	Last seen time, for entry maintain
U8INT u8Status	Sync status

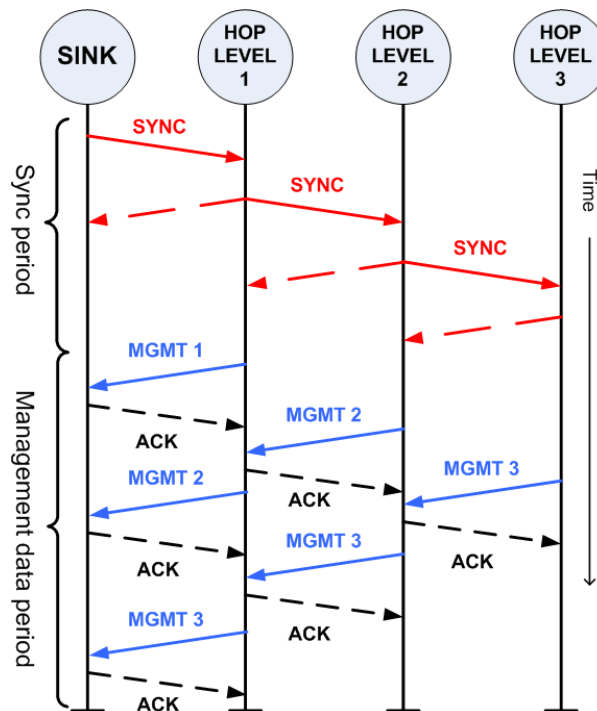
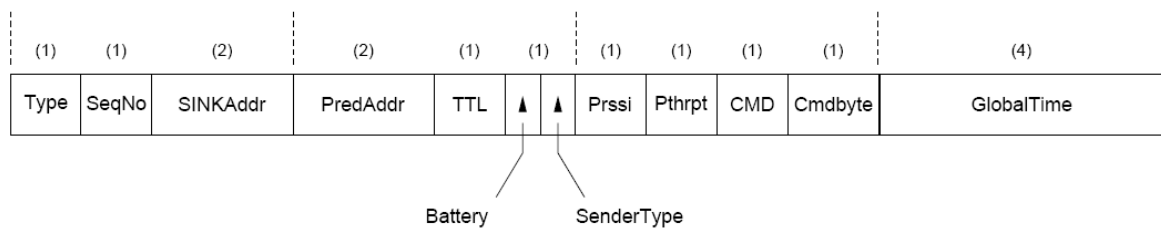


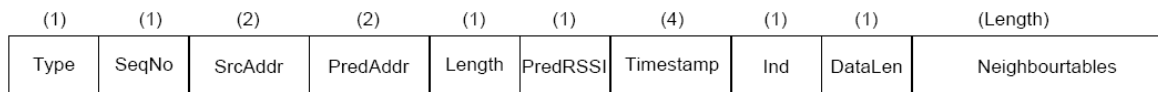
Fig. 3. Synchronization, management and ACK messages during one synchronization period.

After every synchronization period, every node in the network now has real time information about the network around, including information about the sink node. After the synchronization period, the nodes also can send the neighbourtable information through the sink node to the server during the management period. The time interval of this neighbourtable update can be defined to meet the application demands. Typical update interval is one synchronization period, but it can also be much longer.

The management frame includes a section where the neighbourtable information is sent. The management frame structure is shown in Fig. 4(b) Diagnostic and other management data is sent (and acknowledged) as a unicast transmission through a selected route to the sink node. If retransmissions are not needed, each management frame is sent once in every management period.



(a) SYNC frame structure



(b) MGMT frame structure

Fig. 4. Synchronization and management frame structure.

3.2. Neighbourtable Utilization in CiNet Network

Neighbourtables are specially used for collecting information for real time deployment and for monitoring of the WSN. They can be locally used in the nodes or with some management tool. Since every neighbourtable of every node is known, it is possible to count and utilize different diagnostic values about the whole network using the information collected to the neighbourtables.

One of the most useful values that can be calculated from the neighbourtable information is the throughput of one link. The throughput value can directly indicate the reliability and robustness of the sensor node or a link between two nodes. A good throughput values should be near 100 %, but in WSNs typically at least some of the packets are missed. Since network synchronization is done periodically, the node knows how many times it should have heard the synch message after having received the first synch message. The sequence number of the received message is checked, and if the number has increased more than one, then a packet or packets has been missed. The throughput information is calculated based on the nodes' packet counter values and then updated to the nodes' neighbourtable.

When a node has been working for a while, the throughput value will settle to some level that will indicate the basic information about the links reliability. If the throughput value suddenly decreases, it will be a clear indication about something having changed or broken in the network, for example, a car might have been parked between two nodes, interfering with the signal.

RSSI values can be used to determine whether the link is acceptable or not. The nodes typically have been programmed to respond to a predefined RSSI lower bound to determine whether the link is strong enough to be useful. In WSNs, radios typically operate in the 2.4 GHz ISM band and are based on the IEEE 802.15.4 standard due to which RSSI value -85 dBm is considered to be the acceptable lower bound and according to [17] RSSI value -75 dBm or greater indicates over 90 % packet reception rate (PRR) over single link. It is also possible that the link quality may only be suffering from temporary deterioration, for example when objects, such as people and cars, suddenly cross between the nodes. Therefore the neighbour RSSI values also need to be averaged to avoid useless routing changes. Since the data packets' path RSSI value, from node to sink or vice versa, cannot be any larger than the worst link's case, the path RSSI values indicate the lowest RSSI value between the sink and the node. This information can directly be used in packet sending and routing decisions. Meier et al. [5] have used RSSI values too, but also, e.g., number of packets, average packet reception rate and link quality indicator (LQI) to perform efficient WSN link diagnostic.

A node's battery level information can be used to alert the network supervisor to do network maintenance. If a low battery level is noticed before a link stops working, due to power out, it is possible to keep the network topology controlled. Another point is that if the node's battery level is decreasing more rapidly than in the other nodes, it is possible that that the node is not working correctly, or that it is relaying too much data. The battery levels of the nodes' neighbours can also be used to define the data routing. If the battery level of one node is getting low, then an alternatively routing is used, if possible, to avoid unnecessary dropouts.

For packet routing, nodes typically use basic routing tables. Using the routing table, nodes can efficiently transfer data from each node to a sink, but the routing decisions can be thoroughly justified with the extended information of the neighbourtables. In some solution the routing tables can be simplified just to be a list of addresses whose order can be predefined according to the cost metric information in the neighbourtables. Naturally, the nodes' address information is the most important, but other information can be used to optimize the networks' routing performance and reliability. Almost all the information that the neighbourtable contains can be used to improve the network's data routing. In most cases node addresses and some cost metric are used together to create the most energy efficient route for the transmitted data packets.

In our solution, the routing protocol can use hop count and RSSI values to help the decision of the optimal packet transmission direction and route. The minimum hop metric is used in many routing protocols due to its simplicity and isotonicity [18]. Hop count value can directly indicate the logically shortest transmission path from a node to a sink. RSSI values also indicate the links' or the whole paths' quality. In order to maximize packet throughput, it is reasonable to choose links that are more likely by the next relay. Throughput values indicate the total amount of packets that have successfully been transmitted through a specific link. If a link has a good throughput value, it is more likely to perform the transmission successfully again.

Transmitting power for the nodes' radios can also be optimized using the RSSI information in the neighbourtables. In some applications and hardware solutions, it is possible to adjust the radio chips' transmitting power in real time. An acceptable lower bound of RSSI can be fixed, and, based on it, the transmitting powers can be lowered or increased when necessary.

4. The Cost of Neighbourtables

In CiNet network, the nodes are synchronized periodically to ensure valid operation. The length of the synchronization period, during which the neighbourtables are collected, depends on the application

used and on the WSN measurement solution. Thus, data collection is embedded to the synchronization messages, and no extra messages are needed to be sent to collect the neighbourtable information. The maximum size of the SYNC frame is 16 bytes. Of these, 4 bytes are directly related to the neighbourtable usage. It can be stated that basically almost all information in the SYNC frame would be sent even without the neighbourtable usage, since the information is used for routing protocols in any case. Therefore, it can be said that the neighbourtables are filled with almost free of additional energy cost. Only the size of the synchronization frame is increased. Based on the standard it takes $32 \mu\text{s}$ to transmit a one byte. The cost of the neighbourtable construction is caused from these 4 extra bytes for every transmitted SYNC frame. The energy cost of the neighbourtable construction in one node during one broadcasted SYNC frame is $13.8 \mu\text{J}$. The energy cost of the SYNC frame is calculated similarly as defined later for the management frames energy cost. The SYNC frame is broadcasted and therefore the construction cost of the whole networks depends on the number of the nodes.

The memory space is limited in the sensor nodes. As every node can store the information of eight neighbours and as 18 bytes of memory have been reserved for each neighbour, this means a maximum memory use of 144 bytes (8×18 bytes). From these, the six best are sent in the management phase (one management frame can fit six neighbours).

The main additional cost of the neighbourtables incurs when the tables are also sent to the sink node as a part of the management frame. This increases the number of sent packets and time to spend for sending the data. It also consumes more energy. The total cost of one sent and received management frame is defined as

$$E_{frame} = \Delta E_{tx} + \Delta E_{rx} \quad (1)$$

$$\Delta E_{tx} = P_{tx} * t * U_{bat} \quad (2)$$

$$\Delta E_{rx} = P_{rx} * t * U_{bat}, \quad (3)$$

where ΔE_{tx} and ΔE_{rx} are the transmitting and receiving energy consumptions respectively. Communication time between nodes to transmit and receive one neighbourtable is t , the used battery voltage is U_{bat} . P_{tx} and P_{rx} are the transmitting and receiving energy consumptions. The CiNet nodes' numerical characteristic values with Atmega128L+TI CC2420 2.4 GHz transceiver for energy consumption based to our own measurements and datasheet information are shown in Table 3.

Table 3. CiNet nodes' power consumption with Atmega128L+TI CC2420 2.4 GHz transceiver.

P_{tx}	Transmission power consumption	30 mA
P_{rx}	Receiving power consumption	19.7 mA
t	Communication time for one full (6 x 18 bytes) neighbourtable	2 ms
U_{bat}	Used battery voltage	3.6 V

The energy overhead cost of transmitting and receiving one management frame, with full neighbourtable information (6 x 18 bytes) is illustrated in Fig. 5. When only the energy cost from the radio transmission and receiving are taken into account and excluding all the energy losses caused by the measurement sensors and devices, our measurements and calculations have shown that a management frame transmission takes about 0.216 mJ of energy and receiving takes about 0.142 mJ, so the total consumption is about 0.4 mJ [2, 19, 20].

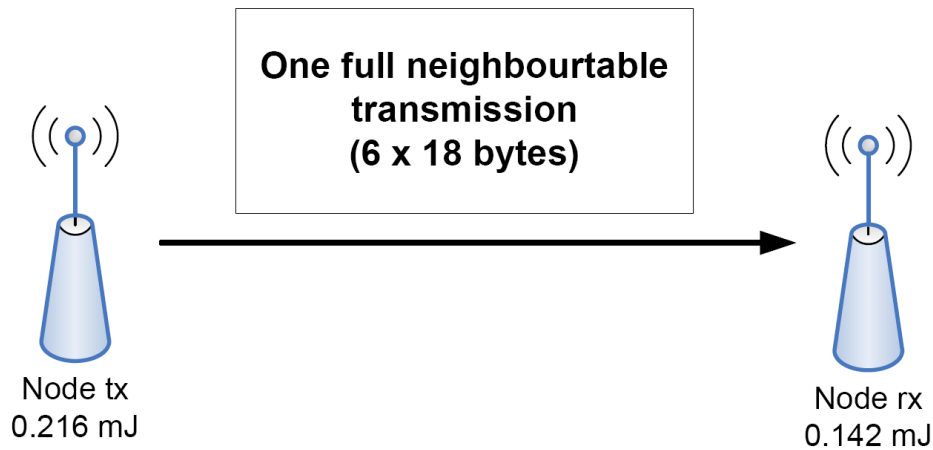


Fig. 5. Energy costs of transmitting and receiving one full neighbourtable.

The energy overhead of the whole network to transmit the neighbourtables to the sink node depends on many different factors. These include, for example, the size of the network used, the number of hops and the application that determines the number of sent and relayed packets. The transmission time of one node is determined by the size of the sent packet. The node's transmission power and battery voltage also affect energy consumption. The size of one transmitted management frame that includes the neighbourtables is between 50 and 128 bytes, depending on the number of the node's neighbours.

5. CiNetView: a Neighbourtable Utilization Tool

Neighbourtables can be used to help sensor network diagnostic and visualization. We have been using neighbourtables in our CiNetView application [21]. The CiNetView application is a graphical tool for making the deployment and monitoring of a WSN easier and more assured. CiNetView is based on diagnostic information that the nodes have collected and stored to neighbourtables. The application is server-centralized and it reads information from the neighbourtable file. CiNetView can be used in both indoor and outdoor deployment cases. If the physical location of the sensor nodes are not exactly known, then the application displays network topology based on relative locations produced by the MDS-algorithm, example is shown in Fig. 6. The MDS-algorithm can also be used to define approximated locations for the sensor nodes, based on the RSSI values, by using different signal propagation models. If it is possible to get an aerial photo, cartogram, map or perhaps a blueprint from the network deployment area, it can then be given as a background image to the application, where the user can exactly pinpoint the nodes' true locations, example is shown in Fig. 7.

The user can select different variables, such as RSSI and throughput of the nodes that are displayed individually over the link lines by the application. Based on the selection CiNetView displays the essential network diagnostic information and helps the user to see the changes in the network's behaviour. The different network variables are read straight from the neighbourtable data file. Because of the real time presentation of the network's connections and the quality of these connections, the advantages of this application can be seen most clearly in the network's deployment phase. The application can be used to diagnose and monitor a WSN through the network's lifetime.

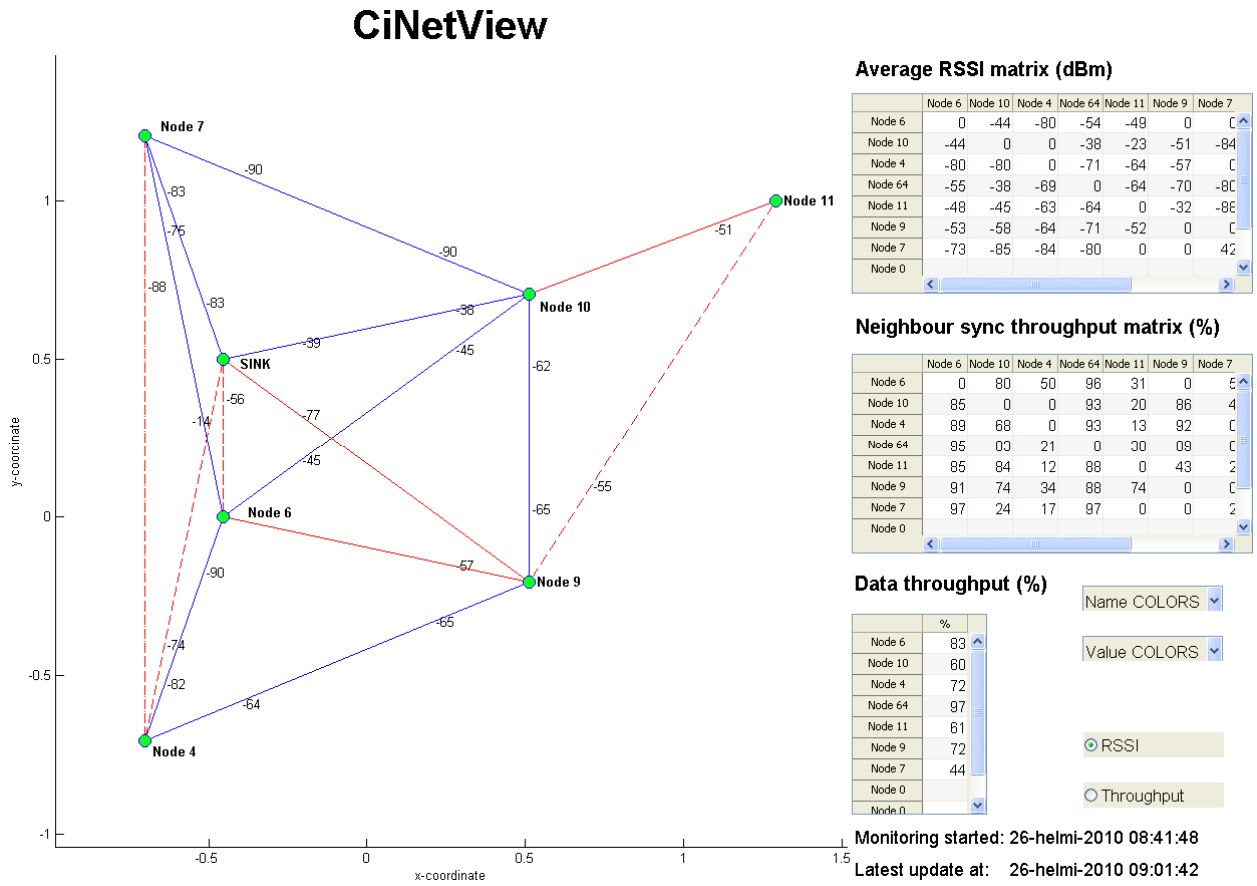


Fig. 6. CiNetView's MDS-algorithm based topology presentation.

Monitoring started: 25-helmi-2010 17:58:16
Latest update at: 25-helmi-2010 19:09:44

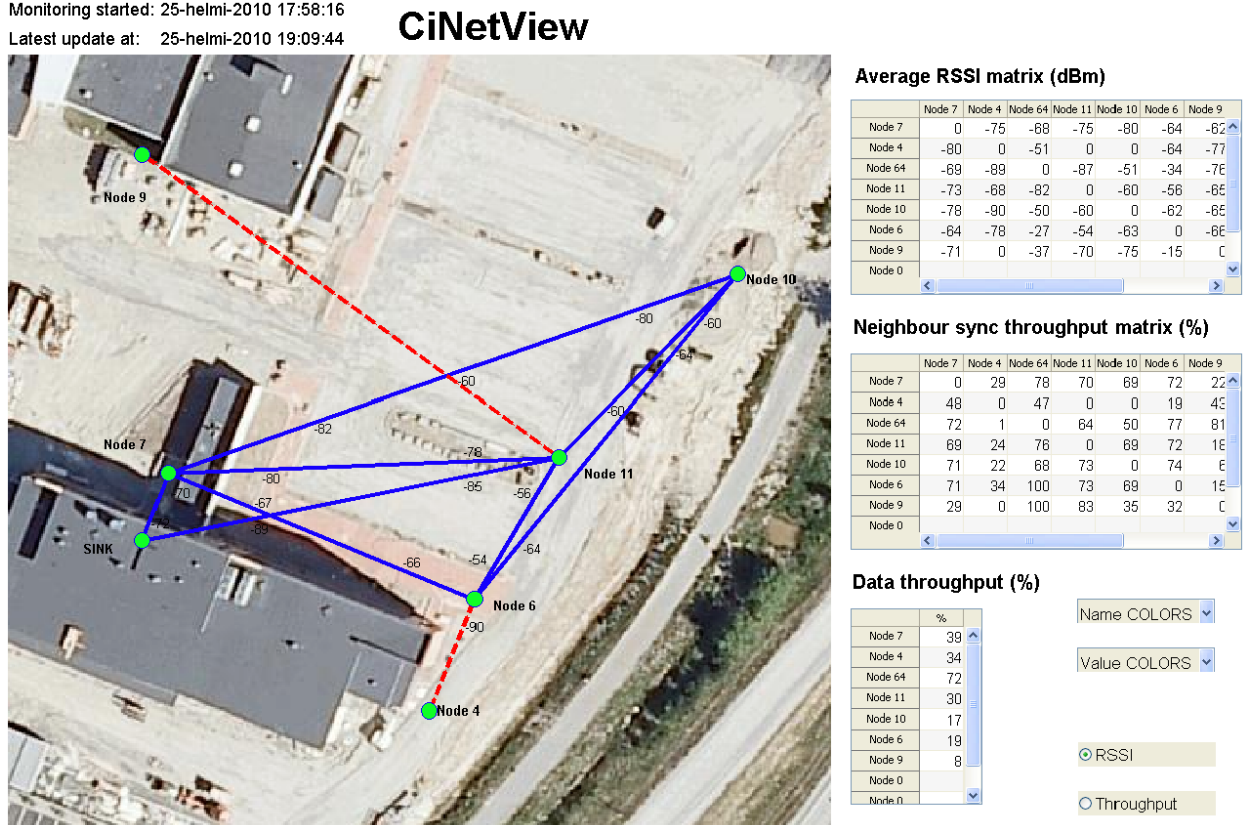


Fig. 7. Parking area of University Consortium Chydenius in Kokkola.

6. Conclusions

In this paper, we have discussed the main topics about wireless sensor network diagnostics and defined the essential metrics for WSN diagnostics. We have presented how the CiNet neighbourtables are constructed, without significant additional transmission overhead, using modified network synchronization messages. In every node they are stored to common data storage in the cross-layer management entity, where all the protocol stack layers can utilize the same information. The cost of the neighbourtables stays relatively small. The neighbourtables can be used locally by the networks' nodes or server centralized in WSN diagnostic and management, for example by using CiNetView application, which is specially designed for WSN visualization and monitoring. The information stored to neighbourtables can also be used in routing protocols to define the best packet routing selection.

For future work the idea is to improve the utilization of the neighbourtables from the nodes' point of view and in general diagnostic applications. The goal is to make a database that collects historical data from the wireless sensor network and can be used in backtracking errors that have been noticed in the network. The energy cost of the neighbourtables will be studied more specifically for all the ported platforms.

Acknowledgements

The work presented in this paper was supported by LuTek-project, funded by the Regional Council of Central Ostrobothnia and European Union structural funds.

References

- [1]. Y. Chen, J. Chiang, H. Chu, P. Huang, and A. Tsui, Sensor-Assisted WI-FI Indoor Location System for Adapting to Environmental Dynamics, in *Proceedings of the 8th ACM Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems*, Montreal, Quebec, Canada, October 10-13 2005.
- [2]. I. Hakala, J. Ihalainen, I. Kivelä, and M. Tikkakoski, Evaluation of Environmental Wireless Sensor Network - Case Foxhouse, *International Journal on Advances in Networks and Services*, Vol. 3, No. 1 and 2, September 2010, pp. 22 – 32.
- [3]. Y. Hu, D. Li, X. He, T. Sun, and Y. Han, The Implementation of Wireless Sensor Network Visualization Platform based on Wetland Monitoring, in *Proceedings of the 2nd International Conference on Intelligent Networks and Intelligent Systems*, 2009.
- [4]. I. Hakala and T. Hongell, Wireless CiNet Network Analysis and Diagnostics Using Neighbourtables, in *Proceedings of the 5th International Conference on Sensor Technologies and Applications (SENSORCOMM' 11)*, August 2011, pp. 110–115.
- [5]. A. Meier, T. Rein, J. Beutel, and L. Thiele, Coping with Unreliable Channels: Efficient Link Estimation for Low- Power Wireless Sensor Networks, in *Proceedings of the 5th International Conference on Networked Sensing Systems (INSS' 08)*, 2008, pp. 19 – 26.
- [6]. G. Ferrari, P. Medagliani, S. Di Piazza, and M. Martalò, Wireless Sensor Networks: Performance Analysis in Indoor Scenarios, *EURASIP Journal on Wireless Communications and Networking*, 2007.
- [7]. A. Fynn, Performance analysis of wireless sensor networks, *Washington University in St. Louis*, Available at: [http://www1.cse.wustl.edu/~jain/cse567-06/sensor perf.htm](http://www1.cse.wustl.edu/~jain/cse567-06/sensor%20perf.htm), Tech. Rep., 2006.
- [8]. A. Jacuot, J.-P. Chanet, K. M. Hou, X. Diao, and J.-J. Li, Livencm : A new wireless management tool, *IEEE AFRICON 2009*, September 2009, pp. 1–6.
- [9]. M. Turon, MOTE-VIEW: A Sensor Network Monitoring and Management Tool, in *Proceedings of the 2nd IEEE Workshop on Embedded Networked Sensors*, 2005, pp. 11 – 18.
- [10]. Wireless Sensor Network: Getting Started Guide, *Crossbow Technology, Inc.*, September 2005.
- [11]. Z. Yao, J. Jiang, P. Fan, Z. Cao, and V. O. K. Lit, A Neighbor-Table-Based Multipath Routing in Ad Hoc Networks, in *Proceedings of the 57th IEEE Semiannual Vehicular Technology Conference*, Vol. 3, 2003, pp. 1739 – 1743.

- [12].C.-S. Nam, H.-Y. Cho and D.-R. Shin, Efficient Path Setup and Recovery in Wireless Sensor Networks by using the Routing Table, in *Proceedings of the 2nd International Conference on Education Technology and Computer (ICETC)*, Vol. 4, 2010, pp. V4–156 – V4–159.
- [13].H. Liu and S. S. Lam, Neighbor Table Construction and Update in a Dynamic Peer-to-Peer Network, in *Proceedings of the 23rd International Conference on Distributed Computing Systems*, 2003, pp. 509 – 518.
- [14].I. Hakala and M. Tikkakoski, From vertical to horizontal architecture: a cross-layer implementation in a sensor network node, in *Proceedings of the 1st International Conference on Integrated Internet Ad Hoc and Sensor Networks*, Vol. 138, No. 6, 2006.
- [15].NXP. Laboratories, Data Sheet: JN5148-001-Myy JenNet, ZigBee PRO and IEEE802.15.4 Module, CHIPCON, Available at: http://www.jennic.com/files/support_files/JN-DSJN5148MO-1v4.pdf
- [16].Atmel Corporation, Datasheet ZigBitZ 700/800/900 MHz Wireless Modules, Available at: http://www.atmel.com/dyn/resources/prod_documents/doc8227.pdf
- [17].R. Maheshwari, S. Jain and S. R. Das, A Measurement Study of Interference Modeling and Scheduling in Low-Power Wireless Networks, in *Proceedings of the 6th ACM conference on Embedded Network Sensor Systems (SenSys '08)*, 2008, pp. 141 – 154.
- [18].W. Dargie and C. Poellabauer, Fundamentals of Wireless Sensor Network: Theory and Practice, ser. Wiley Series on Wireless Communications and Mobile Computing, (X. Shen and Y. Pan, Eds.), *John Wiley & Sons Ltd*, Chichester, United Kingdom, 2010.
- [19].Texas Instrumens, Data Sheet for CC2420 2.4GHz IEEE 802.15.4 RF transceiver, CHIPCON, Available at: <http://focus.ti.com/lit/ds/symlink/cc2420.pdf>
- [20].I. Kivelä, C. Gao, J. Luomala, J. Ihalainen, and I. Hakala, Design of Networked Low-Cost Wireless Noise Measurement Sensors, *Sensors & Transducers*, Vol. 9, Special Issue, February 2011, pp. 171–190.
- [21].I. Hakala, T. Hongell, and J. Luomala, CiNetView - Graphic Interface for Wireless Sensor Network Deployment and Monitoring, in *Proceedings of the 4th International Conference on Sensor Technologies and Applications (SENSORCOMM' 10)*, July 2010, pp. 395 – 401.

2012 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(<http://www.sensorsportal.com>)



**Sensors Industry
News**

**FREE Monthly
IFSA Newsletter**

ISSN 1726-6017

SUBSCRIBE NOW
subscribe@sensorsportal.com

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In addition, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

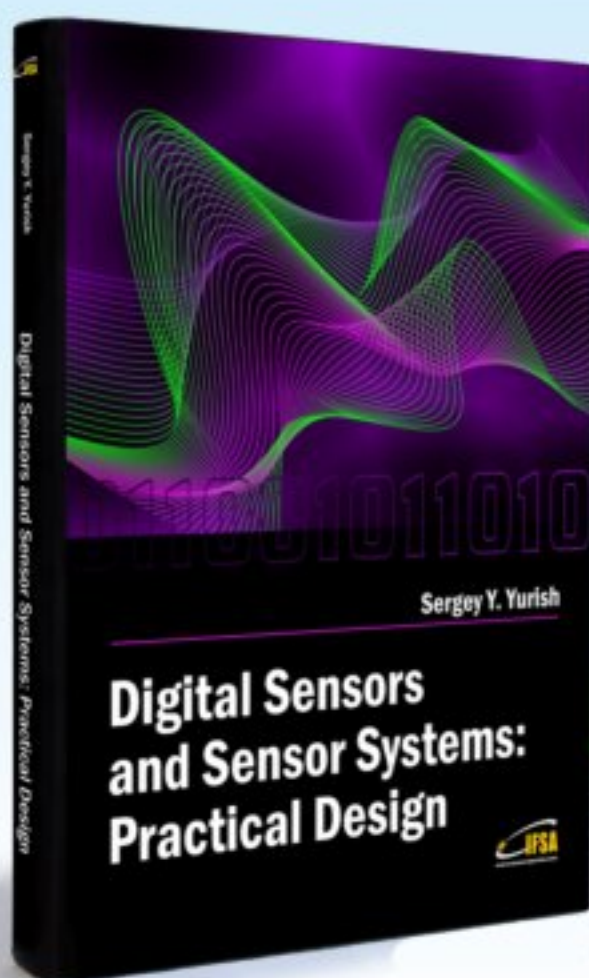
Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2012.pdf

Digital Sensors and Sensor Systems: Practical Design will greatly benefit undergraduate and at PhD students, engineers, scientists and researchers in both industry and academia. It is especially suited as a reference guide for practitioners, working for Original Equipment Manufacturers (OEM) electronics market (electronics/hardware), sensor industry, and using commercial-off-the-shelf components, as well as anyone facing new challenges in technologies, and those involved in the design and creation of new digital sensors and sensor systems, including smart and/or intelligent sensors for physical or chemical, electrical or non-electrical quantities.



"It is an outstanding and most completed practical guide about how to deal with frequency, period, duty-cycle, time interval, pulse width modulated, phase-shift and pulse number output sensors and transducers and quickly create various low-cost digital sensors and sensor systems ..." (from a review)

Order online:

http://www.sensorsportal.com/HTML/BOOKSTORE/Digital_Sensors.htm



www.sensorsportal.com