

ISSN 1726-5479

# SENSORS & TRANSDUCERS

7<sup>vol. 142</sup>  
/12



## Sensor Networks and Wireless Sensor Networks

International Frequency Sensor Association Publishing



**Editors-in-Chief:** professor Sergey Y. Yurish, tel.: +34 696067716, 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**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 Eastern Europe**

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

**Editor for Asia**

Ohyama, Shinji, Tokyo Institute of Technology, Japan

**Editor for Africa**

Maki K.Habib, American University in Cairo, Egypt

**Editor for Asia-Pacific**

Mukhopadhyay, Subhas, Massey University, New Zealand

**Editorial Advisory Board**

- Abdul Rahim, Ruzairi**, Universiti Teknologi, Malaysia  
**Ahmad, Mohd Noor**, Northern University of Engineering, Malaysia  
**Annamalai, Karthigeyan**, 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, Vygtantas**, 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 Motors 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**, Universitè 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, Alexander**, 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  
**Driljaca, 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  
**Kaniasas, 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, Sihua**, Agiltron, Inc., USA  
**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  
**Mishra, Vivekanand**, National Institute of Technology, India  
**Moghavvemi, Mahmoud**, University of Malaya, Malaysia  
**Mohammadi, Mohammad-Reza**, University of Cambridge, UK  
**Molina Flores, Esteban**, Benemérita 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  
**Passaro, Vittorio M. N.**, Politecnico di Bari, Italy  
**Penza, Michele**, ENEA C.R., Italy  
**Pereira, Jose Miguel**, Instituto Politecnico de Setebal, 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  
**Raoof, 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 Politècnica de Catalunya, Spain  
**Rodriguez, Angel**, Universitat Politècnica de Catalunya, 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, Selemani**, Alabama A & M University, USA  
**Seifter, Achim**, Los Alamos National Laboratory, USA  
**Shah, Kriyang**, La Trobe University, Australia  
**Sankarraaj, Anand**, Detector Electronics Corp., USA  
**Silva Giroa, Pedro**, Technical University of Lisbon, Portugal  
**Singh, V. R.**, National Physical Laboratory, India  
**Slomovitz, Daniel**, UTE, Uruguay  
**Smith, Martin**, Open University, UK  
**Soleimanpour, Amir Masoud**, University of Toledo, USA  
**Soleymanpour, Ahmad**, University of Toledo, USA  
**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 Comp. Technol. Center, Thailand  
**Sun, Chengliang**, Polytechnic University, Hong-Kong  
**Sun, Dongming**, Jilin University, China  
**Sun, Junhua**, Beijing University of Aeronautics and Astronautics, China  
**Sun, Zhiqiang**, Central South University, China  
**Suri, C. Raman**, Institute of Microbial Technology, India  
**Sysoev, Victor**, Saratov State Technical University, Russia  
**Szewczyk, Roman**, Industr. 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  
**Thumbavanam 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  
**Vrba, 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, Quintao**, 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 142  
Issue 7  
July 2012

www.sensorsportal.com

ISSN 1726-5479

## Editorial Book Review

### Non-Dispersive Infrared Gas Measurement

*Sergey Y. Yurish, International Frequency Sensor Association (IFSA)* ..... 1

## Research Articles

### Research in Nanothermometry. Part 6. Metrology of Raman Thermometer with Universal Calibration Artifacts

*Bohdan Stadnyk, Svyatoslav Yatsyshyn, Oleh Seheda* ..... 1

### A Survey of Power-Efficient Gathering of Sensor Information System Based Routing Protocols of Wireless Sensor Networks

*Muktar Hussaini, Farhat Anwar, Aisha Hassan A. H.* ..... 10

### Comparative Analysis of Energy-efficient Cluster-based Routing Protocols for Wireless Sensor Networks

*Naveen Kumar V and Santhi Prabha I* ..... 23

### TDMA Based Slotted Medium Access Control Protocol for Wireless Sensor Networks

*Prasan Kumar Sahoo* ..... 33

### Circuit of Data Aggregation on the Fly for WSN

*M. Daoui, M. Lalam, S. Hamrioui B. Djama and D. Nouali* ..... 44

### Dynamic Analysis of Wireless Sensor Network Programs Based on Binary Tool and Simulator

*Yuxia Sun, Yong Tang* ..... 54

### Circle Intersection Method Combined with Fuzzy Weighted Centroid Method for Localization in WSNs

*Mohan Kumar J, P.R. Venkateswaran, N. Gopalakrishna Kini, Sundaresan C.* ..... 61

### Development of an Automatic Wireless System Applied for Soil Temperature Measurement

*S. Makhlof, M. Laghrouche* ..... 69

### Theoretical Analysis to Capacitance of RF MEMS Clamped-Clamped Capacitive Switch

*Tian-Jie, Cao* ..... 76

### Deployment of Wireless Sensor Network for the Measurement of Exhaled Nitric Oxide in In-home Healthcare

*Elango Surendran, Mathivanan Natarajan, Arun Venkatesh Krishna, Vairamani Kanagavel, Karunakaran Chandran, Madasamy Thangamuthu, Pandiaraj Manickam.* ..... 87

### Wireless Communication Solution for Health Care Equipment

*Tiago Faustino Andrade, Manuel Rodrigues Quintas, Carlos Moreira da Silva, Maria Teresa Restivo, Maria de Fátima Chouzal and Teresa Maria Amaral* ..... 95

<b>Lateral Control of Aircraft, Considering the Cross-coupling Effect of Yaw and Roll on Each-other Using Fuzzy Logic</b> <i>Vishnu G. Nair, V. I. George, Prahlad K. R.</i> .....	105
<b>A Parametric Study of S- tube Coriolis Mass Flow Meter</b> <i>Arvind K. Rajput, Satish C. Sharma, Marut Shukla, Souvik Roy</i> .....	118
<b>Calibration Method on Machine for Multi-axis Heavy Force Sensor</b> <i>Wei liu, Zhenyuan jia and Qi li</i> .....	130
<b>TiO<sub>2</sub> Thin Film Capacitive Humidity Sensor Based on Sol-gel Technique</b> <i>Manju Pandey, Debdulal Saha, Kamalendu Sengupta, S. S. Islam</i> .....	143

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).

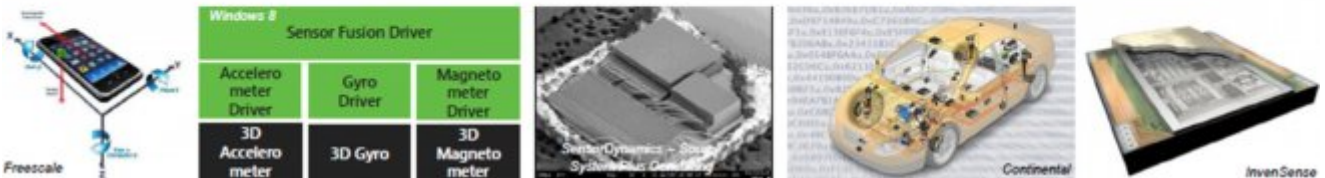
## Inertial Combo Sensors for Consumer & Automotive

### Technology, Applications, Industry & Market Report to 2016



*This report is focused on the analysis of the opportunities and the challenges for inertial combo sensors in those high-volume market areas.*

[http://www.sensorsportal.com/HTML/Inertial\\_Combo\\_Sensors\\_Market.htm](http://www.sensorsportal.com/HTML/Inertial_Combo_Sensors_Market.htm)



## Uncooled Infrared Imaging Market: Commercial & Military applications

### Market & Technology Report to 2016



*This new 2011 IR report, is an updated and in depth analysis of commercial markets covered in the 2010 report in addition we have included a new analysis of the military markets.*

[http://www.sensorsportal.com/HTML/Detectors\\_for\\_Thermography.htm](http://www.sensorsportal.com/HTML/Detectors_for_Thermography.htm)



## A Survey of Power-Efficient Gathering of Sensor Information System Based Routing Protocols of Wireless Sensor Networks

<sup>1</sup>Muktar HUSSAINI, <sup>2</sup>Farhat ANWAR, <sup>3</sup>Aisha HASSAN A. H.

Department of Electrical and Computer Engineering

International Islamic University Malaysia (IIUM)

P. O. Box 10, 53100, Gombak, Malaysia.

E-mail: <sup>1</sup>elhussenkaz@yahoo.com, {<sup>2</sup>farhat, <sup>3</sup>aisha}@iium.edu.my

*Received: 26 March 2012 /Accepted: 23 July 2012 /Published: 31 July 2012*

---

**Abstract:** Energy consumption has to be considered when developing energy-efficient routing algorithms, which has been a challenging issue in the field of WSNs. The idea of LEACH is dynamic clustering that brings extra overhead, such as head changes and advertisements, which may diminish the gain in energy consumption. Moreover, PEGASIS a near optimal chain-based protocol proposed, it was an improvement over LEACH protocol to extend the network lifetime. However, PEGASIS data transmission will create time-delay and, the probability of long chain is always high because of the limitations of greedy algorithm approach for such shortcomings, many protocols was proposed by researchers recently improved algorithms based on PEGASIS such as PEG-Ant, PDCH and PCC et al. Among them, EEPB, and IEEPB was proposed. In this paper, a survey of some routing protocols that are classified based on PEGASIS topology was conducted, and conclude with some open research problems for further research. *Copyright © 2012 IFSA.*

**Keywords:** Protocol, Energy efficiency, Life-time, Energy consumption, Wireless sensor network.

---

### 1. Introduction

Recent advances in technology and the convergence of micro-electro-mechanical systems technology, nanotechnology, integrated circuit technology, wireless communication technology, image and signal processing, ad-hoc networking routing protocols and embedded systems has made the concept of Wireless Sensor Networks (WSNs), which have been broadly considered as one of the most imperative technologies for the twenty first century [1]. Sensor network nodes are limited with respect to communication bandwidth, restricted computational capacity and energy supply. As a result of energy

constraints in sensor nodes, energy consumption has to be considered when developing energy-efficient routing algorithms, which has been a challenging issue in the field of WSNs. Since WSNs might differ depending on the application and network architecture, prolonging the lifetime of the network by designing efficient routing protocols is critical. Most of the attention has been given to the routing protocols with common objectives of trying to extend the lifetime of the sensor networks, while not compromising data delivery. The LEACH [2] (Low-Energy Adaptive Clustering Hierarchy) protocol was proposed by observing and looking at communication protocols, which can have significant impact on the overall energy dissipation of networks. LEACH was proposed to form clusters of the sensor nodes, based on the received signal strength and one node acting as local cluster head serve as router to the sink in order to save energy. In LEACH, the idea of dynamic clustering brings extra overhead, such as head changes and advertisements, which may diminish the gain in energy consumption. Moreover, there are a lot of assumptions used in this protocol which are not implementable for practical purposes. Moreover, PEGASIS [3] a near optimal chain-based protocol proposed, it was an improvement over LEACH protocol to extend the network lifetime. In PEGASIS, each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. It has been outperform LEACH [3] by about 100–300 % for different network sizes and topologies. However, PEGASIS introduces excessive delay, that is; data transmission will create time-delay and, the probability of long chain is always high because of the limitations of greedy algorithm approach that was used for chain construction and data transmission. The method of choosing cluster head or head node is not suitable for load balance. When selecting the head node, there is no consideration about the residual energy of nodes and location of the base station, that is head node can be very far away from BS. In PEGASIS, all sensor nodes have the same level of energy and are likely to die at the same time; it is also assumed that each sensor node is able to communicate with the BS directly, this affect energy efficiency of the nodes for the entire network area. In addition the single leader can also become a bottleneck thus reducing the efficiency significantly. As a results of shortcomings for PEGASIS, many protocols was proposed by researchers recently improved algorithms based on PEGASIS such as PEG-Ant [5], PDCH [9] and PCC [6] et al. Among them, Energy Efficiency PEGASIS Based protocol (EEPB) was proposed by [7], and improved EEPB [8].

This paper is organized as follows: In section 2, the main idea of PEGASIS routing protocol for wireless sensor networks were discussed based on its routing techniques and network topology and its strength and weaknesses. Other protocols based on PEGASIS idea is discussed, and their improved areas are highlighted. Section 3 comprises the summary of the surveyed that highlight some key features of these protocols, section 4 is the conclusion.

## **2. PEGASIS-Based Routing Protocols**

In this section, some PEGASIS-based routing protocols for wireless sensor networks are surveyed and discussed, their strength and weaknesses were also presented.

### **2.1. Power Efficient Gathering in Sensor Information Systems (PEGASIS)**

PEGASIS [3] was proposed to enhance over LEACH protocol. The protocol, called Power Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol. The basic idea of the protocol is to extend network lifetime, nodes need only to communicate with their closest neighbors [3, 4] and they take turns in communicating with the base-station. Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). Gathered data moves from node to node, aggregated and eventually sent to the base station. The

chain construction is performed in a greedy way. PEGASIS has two main objectives. Firstly, increase the lifetime of each node by using collaborative techniques Secondly, allow only local coordination between nodes that are closer so that the bandwidth consumed in communication is reduced. PEGASIS has been shown to outperform LEACH by about 100–300 % [3, 4] for different network sizes and topologies. Such performance gain is achieved through the elimination of the overhead caused by dynamic cluster formation in LEACH and through decreasing the number of transmissions and reception by using data aggregation. The greedy algorithm used to build the chain in the original PEGASIS only achieves a local optimization. However, PEGASIS introduces excessive delay for distant node on the chain also assumes that each sensor node is able to communicate with the BS directly and all sensor nodes have the same level of energy and are likely to die at the same time. In addition the single leader can become a bottleneck. It usually does not operate exhaustively on all the data, so it mostly fails to find the globally optimal solution. Moreover, considering that data will be transmitted along the formed chain, and energy supply is the key restriction of WSN, we should pay more attention to the energy problem.

## **2.2. Improved PEGASIS based on Ant Colony Algorithm**

A protocol using ant colony algorithm was proposed by [5]. The protocol was based on the PEGASIS protocol but using an improved ant colony algorithm rather than the greedy algorithm to construct the chain. The traditional ant colony algorithm is used to solve the Travelling Salesman Problem (TSP) which is to find a loop among some fixed cities. The task is to find a shortest possible tour that visits each city exactly once [5]. Compared with the original PEGASIS, PEGant achieved a global optimization. It forms a chain that makes the path more even-distributed and the total square of transmission distance much less. Moreover, in the constructing process, the energy factor has been taken into account, which brings about a balance of energy consumption between nodes. In each round of transmission, according to the current energy of each node, a leader is selected to directly communicate with the base station (BS).

Ant colony algorithm originates from the actual behavior of ants which communicate with each other by pheromone. Pheromone is a chemical substance released by ants and in turn affecting their moving decisions. Initially, no pheromone is laid on the branches and ants have no bit of information about the length of branches. However, once a shorter one is found, it will receive pheromone at a higher rate. The more quantities ants leave pheromone on the path, the larger probability they visit this path next time. Thus, there will be a positive feedback in the group of ants [5]. In the building process, to choose a node as the next one on the chain, all of the current node's neighbors are candidates and take factors such as the remained energy of the candidate, the amount of consumed energy if we transmit unit data along the branch between the current node and the candidate, and also the quantity of pheromone on the branch as selection standard. The protocol operate in two portions that is, chain building and leader selection.

*Chain Building:* There is assumption that the BS has infinite energy, and all of the nodes initiated by the same amount of energy are located in fixed positions. BS, as the controller, is in time informed each node's current condition such as the position and the remained energy of the node. In data transmitting, the amount of consumed energy is in proportion to the total square of distance. Therefore, there is consideration of the fact that whether the square sum of neighbors' distance along the chain is the minimum as the standard to judge whether it is an optimization [5].

*Leader Selection:* In each round of communication, the node whose current energy is the maximum is selected as the leader. Along the built chain and in the direction of the leader, starting from the end nodes, each node fuses the received data, if it has it available with its own as one packet to transmit to the other neighbor. Eventually, the leader transmits the final fused data to the BS.

From the experiment results compared with the original PEGASIS which uses greedy algorithm to build the chain, PEG-ant protocol was obviously prolong the time when the first node dies. However, because of the consideration of energy factor in both chain building and leader selection to balance energy consumption, all of the nodes almost die at the same time. When the first node dies in PEG-ant protocol, the dead nodes in the original PEGASIS have taken up at least 70 % [5].

### **2.3. Energy Efficiency PEGASIS Algorithm**

Many protocols was proposed by researchers recently improved algorithms based on PEGASIS such as PEG-Ant [5], PDCH [9] and PCC [6] et al. Among them, Energy Efficiency PEGSIS Based protocol (EEPB) was proposed by [7], to adopt threshold when constructing chain to decrease the formation of long link, selects the leader by considering both the residual energy of nodes and the distance between node and BS, and adjusts the reselection frequency of leader according to remaining nodes in the network.

However, EEPB overcomes several problems over PEGASIS but still has deficiencies. When EEPB builds a chain, the threshold adopted is uncertain and complex to determine, which causes the inevitability of long link if valued inappropriately. When EEPB selects the leader, it ignores the suitable proportion of nodes energy and distance between node and BS which optimizes the leader selection according to various application environments [7].

### **2.4. Improved Energy Efficiency PEGASIS Algorithm**

The improvement of energy-efficient PEGASIS-based routing protocol (EEPB) was proposed to solve the problems stated above, which is called IEEPB [8]. The main idea of IEEPB is to compares the distance between nodes twice and finds the shortest path to link the two adjacent nodes. IEEPB is an improved chain-based routing algorithm over EEPB. It is operating by rounds which contain 3 stages: (1) chain construction phase, (2) leader selection phase, (3) data transmission phase.

*Chain Construction Phase:* To form a chain, the algorithm determines the number of nodes, initial energy, and BS location information. Then chain construction start with broadcasts the whole network with a hello message by BS to obtain basic network information such as ID of nodes alive and distance from each node to BS. Then set the node which is farthest from BS as end node, it joins the chain first and is labeled as node 1. End node of the chain obtains the information of distance between itself and other nodes which have not joined the chain yet, finds the nearest node and sets it as node  $i$  waiting to join the chain,  $i$  represents the  $i$ -th node joined. Node  $i$  gets the information of distance between itself and  $i-1$  nodes which are on the chain, finds the nearest node  $j$  ( $1 \leq j \leq i-1$ ) and directly connects with it to join the chain. At this point node  $i$  becomes the new end node of the chain, it recycle and connect node  $i+1, i+2...$ .The process continues till all sensor nodes have joined the chain, so that there forms a branching chain finally.

*Leader Selection Phase:* IEEPB chooses the leader using weighting method which considers both the residual energy of nodes and the distance from node to BS. IEEPB will select the new leader according to the combined weight in each round by estimating distance to BS, which is distance between sensor node and BS. As sensor nodes are location unaware, they have no idea about their geographic location. At initial stage, BS broadcasts information message to the whole network and node  $i$  can estimate its distance from BS by the received signal strength. Then it calculates the energy portion and combined weight for each node. And finally compare the different weights of each node and the node with minimum weight is selected as the leader in this round. The coefficient flexibility optimizes the leader

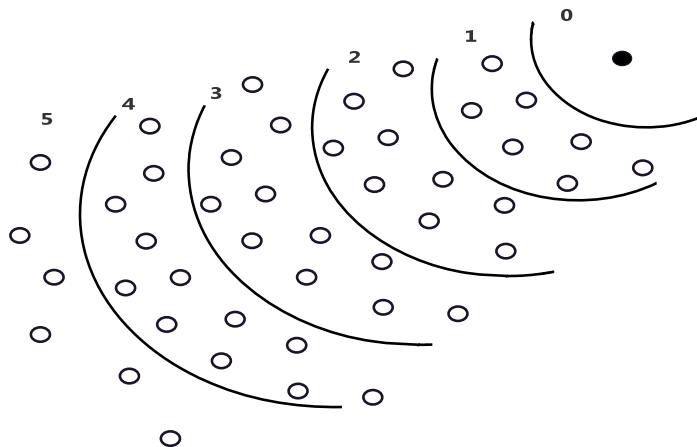
selection and enables the algorithm to be applicable to various network situations with diverse requirements.

*Data Transmission Phase:* After the IEEPB protocol performs the process of the first two phases, the leader initiates a token passing approach to start the data transmission from the end node of the chain. The chain formed in IEEPB has more than two end nodes. Each node delivers own sensing data to its neighbor node in their time slots assigned by TDMA mechanism, then the neighbor nodes fuse them with their own data and transmit these data to their other neighbor nodes. One round will end until BS receives the data from the leader.

## 2.5. Improved PEGASIS Using Concentric Clustering Scheme

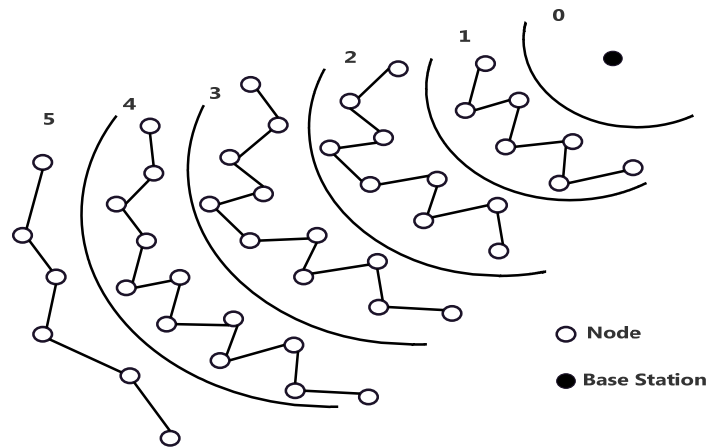
The idea of proposing enhanced PEGASIS protocol using concentric clustering scheme was proposed by [6], due to the redundant data transmission causes by original PEGASIS protocol since one of nodes on the chain is selected as the head node regardless of the base station's location. Enhanced PEGASIS protocol based on the concentric clustering scheme was proposed to solve this problem. The term "concentric clustering" means that the shape of a cluster is concentric circles when the sensor networks are divided into several clusters. It is appropriate to use the concentric clustering scheme to avoid the data transmission attended with the redundant energy consumption. When the PEGASIS protocol constructs the chain, wireless sensor networks are divided into several numbers of the concentric shaped clusters to give the flow of the data transmission. The enhanced PEGASIS protocol consists of four processes (a) level assignment, (b) chain construction in the level area, (c) data transmission and (d) head node construction in chain.

*Level Assignment:* Each node in the sensor networks is assigned its own level from the base station. The level is given as the form like a concentric circle using the signal strength as shown in Fig. 1. The interval of level may varies according to setting values in the base station. Additionally, the number of these levels is depended on various parameters such as the density of the sensor networks, the number of nodes, or the location of the base station [6].



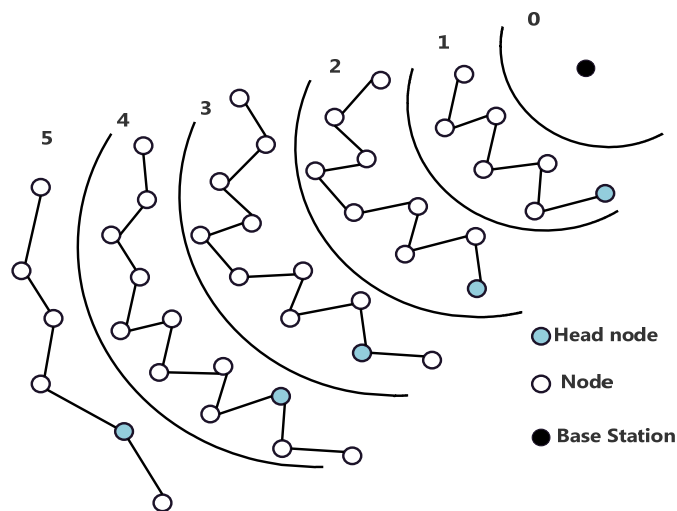
**Fig. 1.** Level Assignment.

*Chain Construction in the Level Area:* In each level area, the chain construction is started at the farthest node from the base station using the greedy algorithm as shown in Fig. 2. This process of the chain construction is the same with the current PEGASIS protocol. In the enhanced PEASIS protocol, the high level means that the node is located at the farther distance from the base station [6].



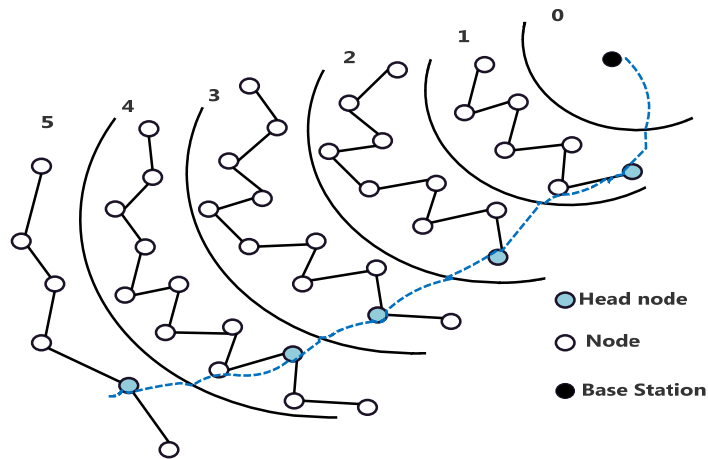
**Fig. 2.** Chain Construction.

*Head node construction in chain:* One of nodes on the chain at each level area is selected as a head node as shown in Fig. 3. A head node in  $L$  level is selected node number  $i \bmod ML$  ( $ML$  presents the number of nodes which have the same level) in  $i$  round. After it selects head nodes, each head node informs its own location information to the upper level head node and lower level head node in one grade. In the process of the data transmission, a head node is received the data from all nodes in the same level and the head node in the upper level. Finally, the head node will transmit these data to the head node in lower level by one grade [6].



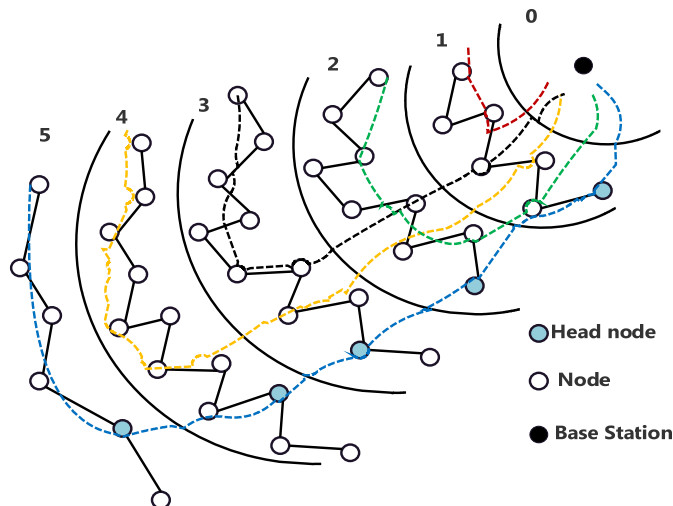
**Fig. 3.** Selection of Head Node.

*Data Transmission:* The data transmission is based on the process of the current PEGASIS protocol. All nodes in each level transmit the data along the chain to the nearest node from themselves. The node receives the data and fuses its own data and transmits these data to the next node. The head node in each level transmits the data to the lower head node. Finally, level 1 head node transmits these data to the base station as shown in Fig. 4. The head node in each level is responsible for receiving the data from node in same level and the head node in upper level. Also, the head node is responsible for transmitting the aggregated data to head node in lower level by one grade [6].



**Fig. 4.** Data Transmission.

Fig. 5 shows the data transmissions from the head node in 3, 4, and 5 levels to the base station. In Fig. 5, the sensor network is divided into five levels considering the location of the base station. All data flow is headed to the base station and it is clear that the concentric clustering scheme makes the sensor networks to avoid a redundant data transmission. Therefore, the energy can be save transmit from each node to the base station and the life time of the wireless sensor networks can be prolong. The enhanced PEGASIS protocol uses the concentric clustering scheme and the data flow always forward to the base station to avoid the redundant transmission of the data and it save the energy about 35% in comparison with the original PEGASIS protocol as the performance evaluation shows [6]. However the protocol does not consider level assignment and the selection of a head node that can also maximize the network life. Also by using greedy algorithm to construct a chain excessive delay may be introduced for distant node.



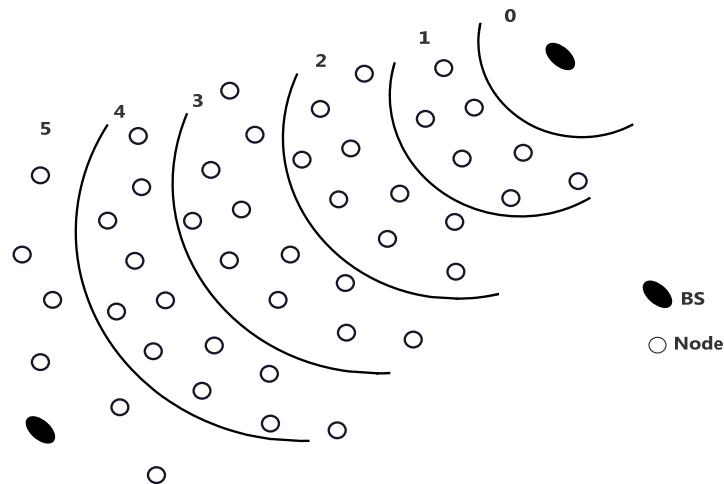
**Fig. 5.** Data Transmission from Each Level.

## 2.6. Improved PEGASIS based on Double Cluster Head

An EEPB algorithm was proposed in [7]. It introduced a new method to avoid long chain between nodes. The new algorithm was proposed based on the branch chained of EEPB to improve the load balance in the network. The new algorithm PDCH was based on double cluster head; it is used

hierarchical chain topology to relief time-delay and adopts bottom level cluster head and super level cluster head to improve the load balance [9].

*Hierarchy and Connection Establishment PDCH:* In the hierarchy structure, base station (BS) is the center of a circle, every node's distance to BS decided the level which it belongs to. The BS will preconfigure the number of levels. Every node receives the signal from the BS, and then according to the signal strength it will detect the distance to BS. The number of nodes and the density of distribution, the location of BS and so on will affect the number of level. And every level has ID. The first level is 0, it belong to BS. The second level is 1, nodes belong to this level is the most closest to BS and so forth. Consider Fig. 6 below, there have 5 levels.



**Fig. 6.** Hierarchy Structure.

The algorithm was adopt the EEPB algorithm to build chains in every level, the nodes belong to different levels cannot build in the same chain, only the nodes with same ID can be built in the same chain. In PDCH [9], there are some changes for building chains. The parameter  $tag[i]$  was set up on every note. If node  $N_i$  have not join in the chains,  $tag[i] = 0$ , when node  $N_i$  was selected by  $N_{i-1}$  to join the chain, the algorithm set  $Tag[i]++$  and  $Tag[i-1]++$ , and so forth, every time when a new node join in a chain, the parameter  $tag[i]$  of select note and was selected note are both automatic accumulate. If  $tag[i] > 2$ , it consider that  $N_i$  has branch chain, in the algorithm PDCH these nodes will become a cluster head preferentially as shown in Fig. 7. In the Fig. 7, the red circles show that, the nodes which the number of tag is more than 2. These nodes have one or more branch chain, so they have bigger chance to be selected as cluster head than other nodes in every level [9].

*The Improving Algorithm of Choosing Double Cluster Head:* Network modeling: The network was model by assumption that all nodes have location information about all other nodes. Nodes would have to expend some extra energy to find their close neighbors. They could do this by sending enough power to signal a node, and then gradually reduce its power to find which neighbor is closest to it. The sensor nodes are homogeneous and energy constrained with uniform energy and no mobility of sensor nodes [9].

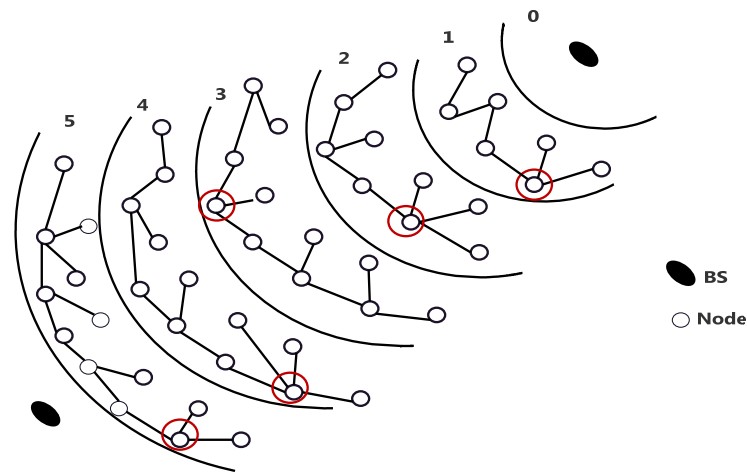


Fig. 7. Building Chain process.

Description of double cluster head algorithm: At every level, there is provision that only the nodes belong to main chain can be the primary cluster head; the nodes belong to branch chain will be selected to be the secondary cluster head. If there is no branch chain in one main chain node at last, it will still use the method of unique cluster head. According to the parameter tag on every node, the more the number of tag  $[i]$  the more priority that the node will be choose. If tag  $[i]$  of the nodes was the same, it will choose the node which has more energy to be the primary cluster head. Then the node selected on the main chain as the primary cluster head, and the node on the branch chain as the secondary cluster head. The primary cluster head and secondary cluster head are both the cluster head in one chain, and they have different work to do. The primary cluster head is in charge of data receiving and fusion, then transmit data to secondary cluster head and the secondary cluster head is in charge of transmitting the lower-level data and the local level data from main cluster head to upper-level cluster-head, and so on. Fig. 8 shows the inter connections of primary cluster head, secondary cluster head, nodes and the base station.

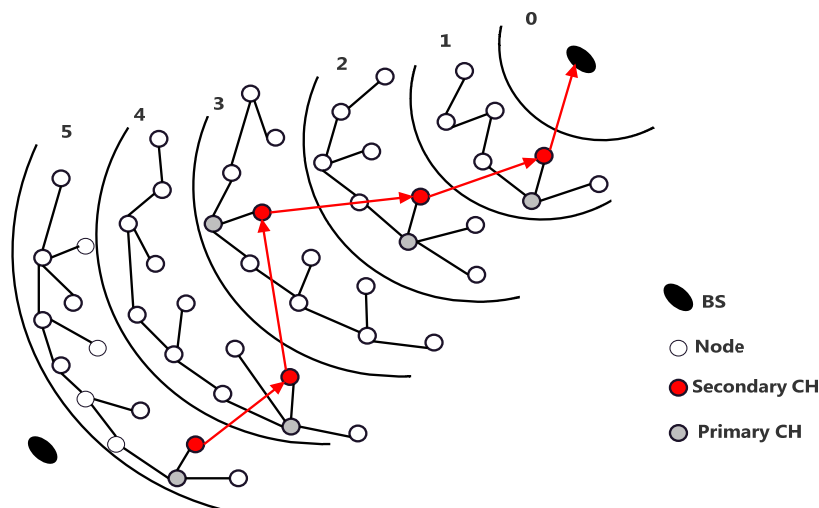


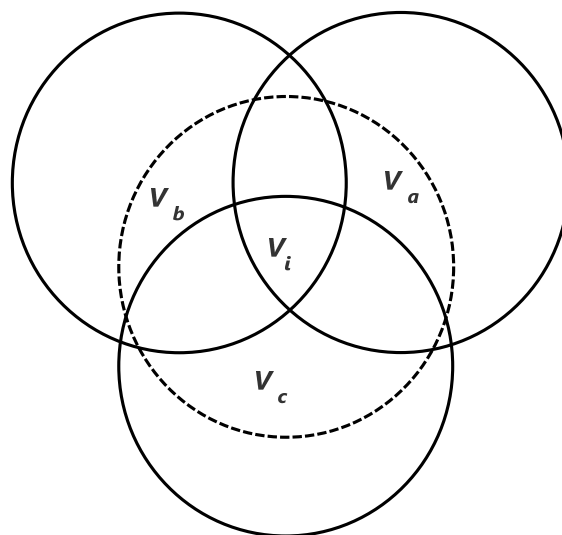
Fig. 8. Double Cluster Head Connections.

From the Fig. 8 above, we can see that the task of one cluster head in PEGASIS have allocated to two nodes in the PDCH, this method make the cluster head work longer time, the efficiency of using

energy rise, and based on this advantage there is reduction of up to frequency of 150 cluster head change. In the process of data transmission, the main cluster head only in charge of receiving data from the local level, so its burden is not as hard as the secondary cluster head. Several candidate secondary cluster head can be set up based on the parameter tag. In the event of rest energy of the secondary cluster head is not enough, it can be change from the candidate secondary cluster head in time. In PDCH, there is no need to rebuild chain in every round, only when there have dead node so as to the cluster head, when the average energy of all primary cluster heads lost 50 %, the cluster head will be selected again in time to make sure the primary cluster head is working [9]. When the secondary cluster head die, its work will turn to the primary cluster head till the round was completed, then consider whether to change the cluster head or not. When the process going to the last, there have not branch chain nodes to leave, then the algorithm will turn to the PEGASIS method [9].

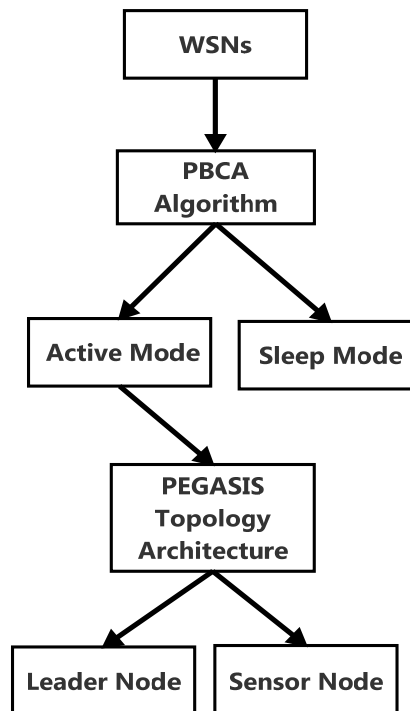
## 2.7. Improved PEGASIS Using Topology Architecture with Coverage Algorithm

*Phase-Based Coverage Algorithm:* As a polynomial-time algorithm operated in an efficient manner, this method is utilized to identify whether the sensing range is fully covered by neighbor nodes with a time complexity  $O(d \log d)$ , where  $d$  represents the number of neighbor nodes around the target sensor node. With assumption that each sensor node shares an identical sensing radius  $R_s$ , and a sensor node  $V_i$ , located at  $(x_i, y_i)$ , covers a sensing range  $C_i$ , then all the sensor nodes staying away from  $V_i$  within the distance  $R_s$ , are covered within  $C_i$ . In the coverage algorithm, there occur some cases where the sensing range of target node  $V_i$  is not fully covered, even though the circumference is altogether covered by neighbor nodes. As a way to resolve the above mentioned problem, as shown in Fig. 2.9, it is requested that the target node  $v_i$  stand away from the neighbor nodes at a distance shorter than the sensing radius [10]. This algorithm, referred to as PBCA, employs circumferential angles and phase to locate the sensor node permitted to enter to sleep mode. To begin with, all the sensor nodes are activated in PBCA. Having located all the sensor nodes in the vicinity of active node  $V_i$  within the sensing radius  $R_s$ , one can recognize through PBCA in a precise manner whether it is a fully covered case according to the circumference of the target sensor field covered by the neighbor nodes. Fig. 9 is an example of a redundant node  $V_i$  [10].



**Fig. 9.** An Example of Redundant Node.

*The PEGASIS Topology Architecture with PBCA:* The topology architecture PEGASIS with the PBCA (phase based coverage algorithm) was proposed by [10]. First, the topology architecture PEGASIS use PBCA to find out the redundant sensor nodes which are covered by other nodes sensing range let these redundant sensor nodes enter to sleep mode to reduce the energy consumption of WSNs. Then, the architecture set up the PEGASIS by other active sensor nodes which are not selected to enter to sleep mode using PBCA. In this algorithm, all the sensor nodes can be classified into two modes; they are sleep and active modes. Subsequently, the smaller number of nodes is active mode to result to less whole energy consumption in each round. At first, the system finds out the redundant sensor nodes by PBCA algorithm. The Fig. 10 below is the flow chart diagram of PEGASIS topology architecture with PBCA [10].



**Fig. 10.** PEGASIS Topology Architecture with PBCA.

The PEGASIS with the PBCA algorithm was divided into three steps, active nodes selection, PEGASIS topology architecture construction and the leader node selection.

1. Active nodes selection: The system will select some sensor nodes to be active nodes using PBCA algorithm which calculates the sensor nodes which sensing range are fully covered by other sensor nodes to enter to sleep nodes.
2. PEGASIS topology architecture construction: The PEGASIS topology architecture was constructed by the active nodes which are selected to enter to active mode via PBCA algorithm.
3. The Leader node selection: Select the sensors that has the farthest distance to base station is used as the starting point of chain, then a sensor nodes that is nearest to it will be found to become its neighbor nodes, by repeating this action several times.

This topology architecture builds more efficient routing for transmitting data compare to LEACH topology architecture with PBCA [10]. And it can reduce much more energy consumption of nodes. Furthermore, the total sensing area of this algorithm is wider than LEACH topology architecture with PBCA for a long time and sensor nodes can live longer. Therefore, PEGASIS with the PBCA algorithm can achieve maximum sensing coverage with minimal energy consumption in each sensor node, and prolong the whole network lifetime. However, PEGASIS with PBCA extend the network

lifetime but still did not solve the problem of selection a cluster head with regard to original PEGASIS. Its also required smaller number of sensor nodes so it is not applicable in a network with huge number of nodes.

### **3. Summary**

In summary, various routing protocols based on PEGASIS topology were discussed and their approaches and architecture was discussed. A protocol using ant colony algorithm was proposed to improve PEGASIS by using an improved ant colony algorithm rather than the greedy algorithm to construct the chain. This is used to solve the Travelling Salesman Problem (TSP) provided by greedy algorithm in PEGASIS. EEPB was proposed to adopt threshold, when constructing chain to decrease the formation of long link, selects the leader by considering both the residual energy of nodes and the distance between node and BS, and adjusts the reselection frequency of leader according to remaining nodes in the network. The improvement of EEPB was proposed to solve the problems of threshold, which is called IEEPB. The main idea of IEEPB is to compares the distance between nodes twice and finds the shortest path to link the two adjacent nodes. Also the enhanced PEGASIS protocol using concentric clustering scheme was proposed, due to the redundant data transmission causes by PEGASIS protocol, since one of nodes on the chain is selected as the head node regardless of the base station's location. Enhanced PEGASIS protocol based on the concentric clustering scheme was proposed to solve this problem. It provides appropriate solution by using the concentric clustering scheme which is the avoidance of data transmission attended with the redundant energy consumption. Furthermore, new algorithm PDCH was proposed based on the branch chained of EEPB to improve the load balance in the network. The algorithm was based on double cluster head; it is used hierarchical chain topology to relief time-delay and adopts bottom level cluster head and super level cluster head to improve the load balance of the WSNs. The topology architecture PEGASIS with the PBCA was also proposed. It is used to find out the redundant sensor nodes which are covered by other nodes sensing range let these redundant sensor nodes enter to sleep mode to reduce the energy consumption of WSNs. Then, the architecture set up the PEGASIS by other active sensor nodes which are not selected to enter to sleep mode using PBCA. These are the protocol based on PEGASIS architecture that are proposed to improved PEGASIS routing protocol, they are proposed with different topology to achieved its aim.

### **4. Conclusion**

Routing in sensor networks is very wide area of research, with a limited, but rapidly growing set of research results and attracted a lot of attention in the recent years with unique challenges compared to traditional data routing in wired networks. In this paper, comprehensive survey of routing protocol based on PEGASIS algorithm was done for wireless sensor networks. All have common objective of trying to extend the lifetime of the sensor network, and provision of energy efficient routing while not compromising data delivery. Although the performance of these protocols is promising in terms of routing and energy efficiency, further research would be needed to address issues such as: Quality of Service posed by video, audio and imaging sensors and real-time applications. Energy-aware QoS routing in sensor networks will ensure guaranteed bandwidth (or delay) through the duration of connection as well as providing the use of most energy efficient path. Consideration of node mobility, most of the current protocols assume that the sensor nodes and the base station are not mobile. Most of the applications in security and environmental monitoring require the data collected from the sensor nodes to be transmitted to a server so that further analysis can be done, so there is need of security and privacy.

## References

- [1]. Li, Yingshu, Thai, My T. and Weili Wu, Wireless Sensor Networks and Applications, *Signal and Communication Technology*, 2008.
- [2]. W. Heinzelman, H. Balakrishnan and A. Chandrakasan, Energy Efficient Communication Protocol for Wireless Microsensor Networks, in *Proceedings of the 33<sup>rd</sup> Hawaii Int. Conf. Syst. Sci., (HICSS '2000)*, January 2000.
- [3]. S. Lindsey and C. Raghavendra, PEGASIS: Power-Efficient Gathering in Sensor Information Systems, in *Proceedings of the Int. Conf. Communication Protocols*, 2001.
- [4]. M. Ilyas (Editor) and I. Mahgoub (Editor), Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems, *CRC Press, LLC*, 2005, pp. 116-138.
- [5]. W. Guo, W. Zhang, G. Lu, PEGASIS Protocol in Wireless Sensor Network Based on an Improved Ant Colony Algorithm, in *Proceedings of the IEEE 2<sup>nd</sup> International Workshop on Education Technology and Computer Science*, Vol. 3, 2010, pp. 64 – 67.
- [6]. S. Jung, Y. Han, T. Chung, The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS, in *Proceedings of the 9<sup>th</sup> International Conference on Advanced Communication Technology*, Vol. 1, 2007, pp. 260.
- [7]. Y. Yong-chang, W. Gang, An Improved PEGASIS Algorithm in Wireless Sensor Network, *Acta Electronica Sinica*, Vol. 36, July 2008, pp. 1309-1313.
- [8]. F. Sen, Q. Bing, T. Liangrui, An Improved Energy-Efficient PEGASIS-Based Protocol in Wireless Sensor Networks, in *Proceedings of the 8<sup>th</sup> IEEE International Conference on Fuzzy Systems and Knowledge Discovery (FSKD' 2011)*, 2011, pp. 2230-2233.
- [9]. W. Linping, C. Zhen, Improved algorithm of PEGASIS protocol introducing double cluster heads in wireless sensor network in *Proceedings of the International IEEE Conference on Computer, Mechatronics, Control and Electronic Engineering (CMCE' 2010)*, 2010.
- [10]. Y. Chen, N. Wang, C. Chen, Y. Lin, A Coverage Algorithm to Improve the Performance of PEGASIS in Wireless Sensor Networks, in *Proceedings of the 12<sup>th</sup> IEEE ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing*, 2011.

---

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

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.iaaria.org/conferences2012/SENSORCOMM12.html>

## 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](mailto: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](mailto:sales@sensorsportal.com) Please download also our media kit: [http://www.sensorsportal.com/DOWNLOADS/Media\\_Kit\\_2012.pdf](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](http://www.sensorsportal.com/HTML/BOOKSTORE/Digital_Sensors.htm)



[www.sensorsportal.com](http://www.sensorsportal.com)