

#### Director of Magazines

Steve Gorshe, PMC-Sierra, Inc (USA)

#### Editor-in-Chief

Osman S. Gebizlioglu, Huawei Tech. Co., Ltd. (USA)

#### Associate Editor-in-Chief

Zoran Zvonar, MediaTek (USA)

#### Senior Technical Editors

Nim Cheung, ASTRI (China)

Nelson Fonseca, State Univ. of Campinas (Brazil)

Steve Gorshe, PMC-Sierra, Inc (USA)

Sean Moore, Centripetal Networks (USA)

Peter T. S. Yum, The Chinese U. Hong Kong (China)

#### Technical Editors

Sonia Aissa, Univ. of Quebec (Canada)

Mohammed Atiqzaman, Univ. of Oklahoma (USA)

Guillermo Atkin, Illinois Institute of Technology (USA)

Mischa Dohler, King's College London (UK)

Xiaoming Fu, Univ. of Goettingen (Germany)

Stefano Galli, ASSIA, Inc. (USA)

Admela Jukan, Tech. Univ. Carolo-Wilhelmina zu

Braunschweig (Germany)

Vimal Kumar Khanna, mCalibre Technologies (India)

Myung J. Lee, City Univ. of New York (USA)

D. Manivannan, Univ. of Kentucky (USA)

Nader F. Mir, San Jose State Univ. (USA)

Seshrati Mohan, University of Arkansas (USA)

Mohamed Moustafa, Egyptian Russian Univ. (Egypt)

Tom Oh, Rochester Institute of Tech. (USA)

Glenn Parsons, Ericsson Canada (Canada)

Joel Rodrigues, Univ. of Beira Interior (Portugal)

Jungwoo Ryo, The Penn. State Univ.-Altoona (USA)

Antonio Sánchez Esguevillas, Telefonica (Spain)

Charalabos Skianis, Univ. of Aegean (Greece)

Ravi Subrahmanyam, InVisage (USA)

Danny Tsang, Hong Kong U. of Sci. & Tech. (China)

Hsiao-Chun Wu, Louisiana State University (USA)

Alexander M. Wyglinski, Worcester Poly. Institute (USA)

Jun Zheng, Nat'l. Mobile Commun. Research Lab (China)

#### Series Editors

##### *Ad Hoc and Sensor Networks*

Edoardo Biagioni, U. of Hawaii, Manoa (USA)

Silvia Giordano, Univ. of App. Sci. (Switzerland)

##### *Automotive Networking and Applications*

Wai Chen, Telcordia Technologies, Inc (USA)

Luca Delgrossi, Mercedes-Benz R&D N.A. (USA)

Timo Kosch, BMW Group (Germany)

Tadao Saito, University of Tokyo (Japan)

##### *Consumer Communications and Networking*

Ali Begen, Cisco (Canada)

Mario Kolberg, University of Sterling (UK)

Madjid Merabti, Liverpool John Moores U. (UK)

##### *Design & Implementation*

Vijay K. Gurbani, Bell Labs/Alcatel Lucent (USA)

Salvatore Loreto, Ericsson Research (Finland)

Ravi Subrahmanyam, Invisage (USA)

##### *Green Communications and Computing Networks*

Daniel C. Kilper, Univ. of Arizona (USA)

John Thompson, Univ. of Edinburgh (UK)

Jinsong Wu, Alcatel-Lucent (China)

Honggang Zhang, Zhejiang Univ. (China)

##### *Integrated Circuits for Communications*

Charles Chien (USA)

Leu Chua-Eoan, Qualcomm (USA)

Zhiwei Xu, SST Communication Inc. (USA)

##### *Network and Service Management*

George Pavlou, U. College London (UK)

Juergen Schoenwaelder, Jacobs University (Germany)

##### *Networking Testing*

Ying-Dar Lin, National Chiao Tung University (Taiwan)

Erica Johnson, University of New Hampshire (USA)

##### *Optical Communications*

Osman Gebizlioglu, Huawei Technologies (USA)

Vijay Jain, Sterlite Network Limited (India)

##### *Radio Communications*

Thomas Alexander, Ixia Inc. (USA)

Amitabh Mishra, Johns Hopkins Univ. (USA)

#### Columns

##### *Book Reviews*

Piotr Cholda, AGH U. of Sci. & Tech. (Poland)

##### *History of Communications*

Steve Weinstein (USA)

##### *Regulatory and Policy Issues*

J. Scott Marcus, WIK (Germany)

Jon M. Peha, Carnegie Mellon U. (USA)

##### *Technology Leaders' Forum*

Steve Weinstein (USA)

##### *Very Large Projects*

Ken Young, Telcordia Technologies (USA)

#### Publications Staff

Joseph Milizzo, Assistant Publisher

Susan Lange, Online Production Manager

Jennifer Porcello, Production Specialist

Catherine Kemelmacher, Associate Editor

# IEEE Communications MAGAZINE

JANUARY 2015, Vol. 53, No. 1

www.comsoc.org/commag

- 6 THE PRESIDENT'S PAGE
- 12 CONFERENCE REPORT/IEEE GLOBECOM 2014
- 16 CONFERENCE PREVIEW/IEEE HPSR 2015
- 18 GLOBAL COMMUNICATIONS NEWSLETTER
- 304 ADVERTISERS' INDEX

## AMBIENT ASSISTED LIVING COMMUNICATIONS

GUEST EDITORS: JOEL J. P. C. RODRIGUES, SUDIP MISRA, HAOHONG WANG, AND ZUQING ZHU

- 24 GUEST EDITORIAL
- 26 A SMART COMMUNICATION ARCHITECTURE FOR AMBIENT ASSISTED LIVING  
JAIME LLORET, ALEJANDRO CANOVAS, SANDRA SENDRA, AND LORENA PARRA
- 34 SMARTPHONE-CENTRIC AMBIENT ASSISTED LIVING PLATFORM FOR PATIENTS  
SUFFERING FROM CO-MORBIDITIES MONITORING  
IGOR BISIO, FABIO LAVAGETTO, MARIO MARCHESE, AND ANDREA SCIARRONE
- 42 OVERCOMING THE CHALLENGE OF VARIETY: BIG DATA ABSTRACTION, THE NEXT  
EVOLUTION OF DATA MANAGEMENT FOR AAL COMMUNICATION SYSTEMS  
RUI MAO, HONGLONG XU, WENBO WU, JIANQIANG LI, YAN LI, AND MINHUA LU
- 48 BAYESIAN COALITION GAME FOR THE INTERNET OF THINGS: AN AMBIENT  
INTELLIGENCE-BASED EVALUATION  
NEERAJ KUMAR, NAVEEN CHILAMKURTI, AND SUBHAS C. MISRA
- 56 LDPA: A LOCAL DATA PROCESSING ARCHITECTURE IN AMBIENT ASSISTED LIVING  
COMMUNICATIONS  
KUN WANG, YUN SHAO, LEI SHU, GUANGJIE HAN, AND CHUNSHENG ZHU
- 64 ASYNCHRONOUS FLOW SCHEDULING FOR GREEN AMBIENT ASSISTED LIVING  
COMMUNICATIONS  
DAN WU, YUMING CAI, AND MOHSEN GUIZANI
- 71 AUTHENTICATION PROTOCOL FOR AN AMBIENT ASSISTED LIVING SYSTEM  
DEBIAO HE AND SHERALI ZEADALLY
- 78 RELIABLE MAC DESIGN FOR AMBIENT ASSISTED LIVING: MOVING THE  
COORDINATION TO THE CLOUD  
ELLI KARTSAKLI, ANGELOS ANTONOPOULOS, ARIS S. LALOS, STEFANO TENNINA,  
MARCO DI RENZO, LUIS ALONSO, AND CHRISTOS VERIKOUKIS

## EXTREMELY DENSE WIRELESS NETWORKS

GUEST EDITORS: CLAUDIO CICONETTI, ANTONIO DE LA OLIVA, DAVID CHIENG,  
AND JUAN CARLOS ZÚÑIGA

- 88 GUEST EDITORIAL
- 90 SPECTRAL AND ENERGY EFFICIENCY OF ULTRA-DENSE NETWORKS UNDER DIFFERENT  
DEPLOYMENT STRATEGIES  
SYED FAHAD YUNAS, MIKKO VALKAMA, AND JARNO NIEMELÄ
- 102 INTERFERENCE COORDINATION FOR DENSE WIRELESS NETWORKS  
BEATRIZ SORET, KLAUS I. PEDERSEN, NIELS T. K. JØRGENSEN, AND VÍCTOR FERNÁNDEZ-LÓPEZ
- 110 UNDERSTANDING CHANNEL SELECTION DYNAMICS IN DENSE WI-FI NETWORKS  
AKASH BAID AND DIPANKAR RAYCHAUDHURI
- 118 PER-NODE THROUGHPUT ENHANCEMENT IN WI-FI DENSENETS  
KYUNGSEOP SHIN, IERYUNG PARK, JUNHEE HONG, DONGSOO HAR, AND DONG-HO CHO
- 126 ON THE EFFICIENT UTILIZATION OF RADIO RESOURCES IN EXTREMELY DENSE  
WIRELESS NETWORKS  
ARASH ASADI, VINCENZO SCIANCALEPORE, AND VINCENZO MANCUSO
- 134 TOWARD 5G DENSENETS: ARCHITECTURAL ADVANCES FOR EFFECTIVE  
MACHINE-TYPE COMMUNICATIONS OVER FEMTOCELLS  
MASSIMO CONDOLUCI, MISCHA DOHLER, GIUSEPPE ARANITI, ANTONELLA MOLINARO,  
AND KAN ZHENG
- 142 DISTRIBUTED MOBILITY MANAGEMENT FOR FUTURE 5G NETWORKS: OVERVIEW AND  
ANALYSIS OF EXISTING APPROACHES  
FABIO GIUST, LUCA COMINARDI, AND CARLOS J. BERNARDOS



**2015 IEEE Communications Society  
Elected Officers**

Sergio Benedetto, *President*  
Harvey A. Freeman, *President-Elect*  
Khaled Ben Letaief, *VP-Technical Activities*  
Hikmet Sari, *VP-Conferences*  
Stefano Bregni, *VP-Member Relations*  
Sarah Kate Wilson, *VP-Publications*  
Rob Fish, *VP-Standards Activities*

**Members-at-Large**

**Class of 2015**

Nirwan Ansari, Stefano Bregni  
Hans-Martin Foisel, David G. Michelson

**Class of 2016**

Sonia Aissa, Hsiao Hwa Chen  
Nei Kato, Xuemin Shen

**Class of 2017**

Gerhard Fettweis, Araceli García Gómez  
Steve Gorshe, James Hong

**2015 IEEE Officers**

Howard E. Michel, *President*  
Barry L. Shoop, *President-Elect*  
Parviz Famouri, *Secretary*  
Jerry L. Hudgins, *Treasurer*  
J. Roberto B. de Marca, *Past-President*  
E. James Prendergast, *Executive Director*  
Harvey A. Freeman, *Director, Division III*

**IEEE COMMUNICATIONS MAGAZINE** (ISSN 0163-6804) is published monthly by The Institute of Electrical and Electronics Engineers, Inc. Headquarters address: IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997, USA; tel: +1 (212) 705-8900; <http://www.comsoc.org/commag>. Responsibility for the contents rests upon authors of signed articles and not the IEEE or its members. Unless otherwise specified, the IEEE neither endorses nor sanctions any positions or actions espoused in *IEEE Communications Magazine*.

**ANNUAL SUBSCRIPTION:** \$27 per year print subscription. \$16 per year digital subscription. Non-member print subscription: \$400. Single copy price is \$25.

**EDITORIAL CORRESPONDENCE:** Address to: Editor-in-Chief, Osman S. Gebizlioglu, Huawei Technologies, 400 Crossing Blvd., 2nd Floor, Bridgewater, NJ 08807, USA; tel: +1 (908) 541-3591, e-mail: [Osman.Gebizlioglu@huawei.com](mailto:Osman.Gebizlioglu@huawei.com).

**COPYRIGHT AND REPRINT PERMISSIONS:** Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limits of U.S. Copyright law for private use of patrons: those post-1977 articles that carry a code on the bottom of the first page provided the per copy fee indicated in the code is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For other copying, reprint, or republication permission, write to Director, Publishing Services, at IEEE Headquarters. All rights reserved. Copyright © 2015 by The Institute of Electrical and Electronics Engineers, Inc.

**POSTMASTER:** Send address changes to *IEEE Communications Magazine*, IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331. GST Registration No. 125634188. Printed in USA. Periodicals postage paid at New York, NY and at additional mailing offices. Canadian Post International Publications Mail (Canadian Distribution) Sales Agreement No. 40030962. Return undeliverable Canadian addresses to: Frontier, PO Box 1051, 1031 Helena Street, Fort Eire, ON L2A 6C7.

**SUBSCRIPTIONS:** Orders, address changes—IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; tel: +1 (732) 981-0060; e-mail: [address.change@ieee.org](mailto:address.change@ieee.org).

**ADVERTISING:** Advertising is accepted at the discretion of the publisher. Address correspondence to: Advertising Manager, *IEEE Communications Magazine*, 3 Park Avenue, 17th Floor, New York, NY 10016.

**SUBMISSIONS:** The magazine welcomes tutorial or survey articles that span the breadth of communications. Submissions will normally be approximately 4500 words, with few mathematical formulas, accompanied by up to six figures and/or tables, with up to 10 carefully selected references. Electronic submissions are preferred, and should be submitted through Manuscript Central: <http://mc.manuscriptcentral.com/commag-ieee>. Submission instructions can be found at the following: <http://www.comsoc.org/commag/paper-submission-guidelines>. For further information contact Zoran Zvonar, Associate Editor-in-Chief ([zoran.zvonar@mediatek.com](mailto:zoran.zvonar@mediatek.com)). All submissions will be peer reviewed.



- 150 **SOFTWARE-DEFINED NETWORKING IN CELLULAR RADIO ACCESS NETWORKS: POTENTIAL AND CHALLENGES**  
MUSTAFA Y. ARSLAN, KARTHIKEYAN SUNDARESAN, AND SAMPATH RANGARAJAN
- 157 **SCALABILITY OF DENSE WIRELESS LIGHTING CONTROL NETWORKS**  
CONRAD DANDELSKI, BERND-LUDWIG WENNING, DANIEL VIRAMONTES PEREZ, DIRK PESCH, AND JEAN-PAUL M.G. LINNARTZ

**MILLIMETER-WAVE COMMUNICATIONS FOR 5G – PART 2: APPLICATIONS**

GUEST EDITORS: MAGED ELKASHLAN, TRUNG Q. DUONG, AND HSIAO-HWA CHEN

- 166 **GUEST EDITORIAL**
- 168 **MULTI-GIGABIT MILLIMETER WAVE WIRELESS COMMUNICATIONS FOR 5G: FROM FIXED ACCESS TO CELLULAR NETWORKS**  
PENG WANG, YONGHUI LI, LINGYANG SONG, AND BRANKA VUCETIC
- 180 **RANDOM ACCESS IN MILLIMETER-WAVE BEAMFORMING CELLULAR NETWORKS: ISSUES AND APPROACHES**  
CHEOL JEONG, JEONGHO PARK, AND HYUNKYU YU
- 186 **LARGE-SCALE ANTENNA SYSTEMS WITH HYBRID ANALOG AND DIGITAL BEAMFORMING FOR MILLIMETER WAVE 5G**  
SHUANGFENG HAN, CHIH-LIN I, ZHIKUN XU, AND CORBETT ROWELL
- 195 **POINT-TO-MULTIPOINT IN-BAND MMWAVE BACKHAUL FOR 5G NETWORKS**  
RAKESH TAORI AND ARUN SRIDHARAN
- 202 **ULTRA-DENSE NETWORKS IN MILLIMETER-WAVE FREQUENCIES**  
ROBERT BALDEMAIR, TIM IRNICH, KUMAR BALACHANDRAN, ERIK DAHLMAN, GUNNAR MILDH, YNGVE SELÉN, STEFAN PARKVALL, MICHAEL MEYER, AND AFIF OSSEIRAN
- 209 **ENABLING DEVICE-TO-DEVICE COMMUNICATIONS IN MILLIMETER-WAVE 5G CELLULAR NETWORKS**  
JIAN QIAO, XUEMIN (SHERMAN) SHEN, JON W. MARK, QINGHUA SHEN, YEJUN HE, AND LEI LEI
- 216 **HYBRID MILLIMETER-WAVE SYSTEMS: A NOVEL PARADIGM FOR HETNETS**  
HANI MEHRPOUYAN, MICHAEL MATTHAIIOU, RUI WANG, GEORGE K. KARAGIANNIDIS, AND YINGBO HUA
- 222 **10 GB/s HETSNETS WITH MILLIMETER-WAVE COMMUNICATIONS: ACCESS AND NETWORKING – CHALLENGES AND PROTOCOLS**  
KAN ZHENG, LONG ZHAO, JIE MEI, MISCHA DOHLER, WEI XIANG, AND YUEXING PENG
- 232 **MILLIMETER-WAVE MULTIMEDIA COMMUNICATIONS: CHALLENGES, METHODOLOGY, AND APPLICATIONS**  
DAN WU, JINLONG WANG, YUMING CAI, AND MOHSEN GUIZANI
- 240 **MULTIMEDIA RESOURCE ALLOCATION IN MMWAVE 5G NETWORKS**  
SANDRA SCOTT-HAYWARD AND EMILIANO GARCIA-PALACIOS

**AD HOC AND SENSOR NETWORKS**

SERIES EDITORS: EDOARDO BIAGIONI AND SILVIA GIORDANO

- 248 **SERIES EDITORIAL**
- 249 **SPARSE REPRESENTATION BASED ACOUSTIC RANGEFINDERS: FROM SENSOR PLATFORMS TO MOBILE DEVICES**  
PRASANT MISRA, SALIL S. KANHERE, SANJAY JHA, AND WEN HU
- 258 **DELAY-TOLERANT NETWORK PROTOCOL TESTING AND EVALUATION**  
YONG LI, PAN HUI, DEPENG JIN, AND SHENG CHEN
- 267 **ON THE POTENTIAL OF BLUETOOTH LOW ENERGY TECHNOLOGY FOR VEHICULAR APPLICATIONS**  
JIUN-REN LIN, TIMOTHY TALTY, AND OZAN K. TONGUZ

**NETWORK AND SERVICE MANAGEMENT**

SERIES EDITORS: GEORGE PAVLOU AND JUERGEN SCHOENWAEELDER

- 276 **SERIES EDITORIAL**
- 278 **SOFTWARE-DEFINED NETWORKING: MANAGEMENT REQUIREMENTS AND CHALLENGES**  
JULIANO ARAUJO WICKBOLDT, WANDERSON PAIM DE JESUS, PEDRO HELENO ISOLANI, CRISTIANO BONATO BOTH, JUERGEN ROCHOL, AND LISANDRO ZAMBENEDDI GRANVILLE
- 286 **A RECOMMENDER SYSTEM ARCHITECTURE FOR PREDICTIVE TELECOM NETWORK MANAGEMENT**  
FAISAL ZAMAN, GABRIEL HOGAN, SVEN VAN DER MEER, JOHN KEENEY, SEBASTIAN ROBITZSCH, AND GABRIEL-MIRO MUNTEAN
- 294 **MANAGEMENT ARCHITECTURE FOR LOCATION-AWARE SELF-ORGANIZING LTE/LTE-A SMALL CELL NETWORKS**  
SERGIO FORTES, ALEJANDRO AGUILAR-GARCÍA, RAQUEL BARCO, FELIX BARBA BARBA, JOSE ANTONIO FERNÁNDEZ-LUQUE, AND ALFONSO FERNÁNDEZ-DURÁN