

Springer Series in Wireless Technology

Ramjee Prasad
Sudhir Dixit *Editors*

Wireless World in 2050 and Beyond: A Window into the Future!

 Springer

Springer Series in Wireless Technology

Series editor

Ramjee Prasad, Aalborg, Denmark

Springer Series in Wireless Technology explores the cutting edge of mobile telecommunications technologies. The series includes monographs and review volumes as well as textbooks for advanced and graduate students. The books in the series will be of interest also to professionals working in the telecommunications and computing industries. Under the guidance of its editor, Professor Ramjee Prasad of the Center for TeleInFrastruktur (CTIF), Aalborg University, the series will publish books of the highest quality and topical interest in wireless communications.

More information about this series at <http://www.springer.com/series/14020>

Ramjee Prasad · Sudhir Dixit
Editors

Wireless World in 2050 and Beyond: A Window into the Future!

 Springer

Editors

Ramjee Prasad
Center for TeleInfrastruktur
Aalborg University
Aalborg
Denmark

Sudhir Dixit
Skydoot, Inc
Woodside, CA
USA

ISSN 2365-4139 ISSN 2365-4147 (electronic)
Springer Series in Wireless Technology
ISBN 978-3-319-42140-7 ISBN 978-3-319-42141-4 (eBook)
DOI 10.1007/978-3-319-42141-4

Library of Congress Control Number: 2016944399

© Springer International Publishing Switzerland 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

सहजं कर्म कौन्तेय सदोषमपि न त्यजेत्
सर्वारम्भा हि दोषेण धूमेनाग्निरिवावृताः

*saha-jam karma kaunteya
sa-dosam api na tyajet
sarvarambha hi dosena
dhumenagnir ivavrtah*

Bhagavad Gita 18.48

Every endeavor is covered by some sort of fault, just as fire is covered by smoke. Therefore one should not give up the work which is born of his nature, O son of Kuntī, even if such work is full of fault.

*To all the past, present, and future Ph.D.
researchers*

Preface

This book is an outcome of a day-long seminar on *wireless and human bond communications beyond the year 2050* held on June 22, 2015 at the Center for Teleinfrastruktur, Department of Electronic Systems, Aalborg University, Denmark, to commemorate the supervision of 100 Ph.D. students by Ramjee Prasad. During the event, 18 presentations were made by the former Ph.D. students and the invited speakers who have attained prominence in their respective fields of endeavors around the world. The talks covered a broad range of topics related to wireless communications. The core theme of the seminar was to fast-forward the future to 2050 and speculate the innovations yet to come, how society would adopt to changes, and what types of strategies and business models would likely be in play in about 35 years' time from now. In short, the seminar was an exercise to create a time capsule for the future generations to look back and determine how correct or wrong the predictions were. The event was such a success that it was decided that the speakers write up position papers on the ideas that they presented. These were then adapted into book chapters to be published collectively in a book.

In addition to discussing overall transformation of the wireless systems of the future from a historical perspective, some authors go into details of likely technological innovations to come and how they would impact certain industries, such as healthcare, automobile, IoT/M2M, entertainment, and the society overall. The past decade has seen many changes in the business models for revenue generation. This trend is going to pick up even more momentum in the future. Therefore, we have chapters included on multi-business models and business strategies to meet the challenges for the 2050 time-frame.

The book is intended for casual readers not necessarily familiar with wireless technologies. Therefore, the content is more descriptive and qualitative than theoretical in style of writing.

We (including the chapter authors) have made every effort to be as accurate as possible, but some errors are inevitable. We encourage the readers to let us know of any errors, which we will correct in future editions of the book.

Aalborg, Denmark
Woodside, USA
June 2016

Ramjee Prasad
Sudhir Dixit

Acknowledgments

We thank the contributors of this book for their time and effort to make this book possible in a short period. They readily agreed to write chapters based on their presentations at a day-long seminar on June 22, 2015, organized at the Aalborg University, to celebrate the successful supervision of the 100 Ph.D. graduates by Ramjee Prasad. The seminar focused on the innovations yet to come in the world of wireless in the beyond 2050 period and the new and emerging field of human bond communication.

Contents

1	Introduction	1
	Sudhir Dixit and Ramjee Prasad	
2	Technology Advancements in 2050 and How the World Will Look Like	7
	Alexandru Vulpe	
3	Beyond the Next Generation Access	17
	Vladimir Poulkov	
4	Ubiquitous Wireless Communications Beyond 2050	41
	Shu Kato	
5	The Networkless Network	49
	Rajarshi Sanyal	
6	Perspectives on Enabling Technologies for Intelligent Wireless Sensor Networks	63
	Homayoun Nikookar	
7	Energy Efficient Joint Antenna Techniques for Future Mobile Communication: Beyond 2050	73
	Bo Han	
8	The Software Defined Car: Convergence of Automotive and Internet of Things	83
	Mahbubul Alam	
9	Future of Healthcare—Sensor Data-Driven Prognosis	93
	Arpan Pal, Arijit Mukherjee and Swarnava Dey	
10	Big Data and Internet of Things—Challenges and Opportunities for Accelerated Business Development Beyond 2050	111
	George Suciu	

11 Cyber Security: Beyond 2050	129
Anand R. Prasad and Sivabalan Arumugam	
12 Defining the ICT Strategy for Beyond 2050.	137
Sofoklis Kyriazakos	
13 Multi Business Model Innovations Towards 2050 and Beyond	149
Peter Lindgren	
14 Epilogue	161
Sudhir Dixit and Ramjee Prasad	
About the Book	165
Index	167

About the Editors



Dr. Ramjee Prasad is the Founder President of the CTIF Global Capsule (CGC). He has been Founding Director of Center for Teleinfrastruktur (CTIF) since 2004. He is also the Founder Chairman of the Global ICT Standardisation Forum for India, established in 2009. GISFI has the purpose of increasing of the collaboration between European, Indian, Japanese, North American, and other worldwide standardization activities in the area of Information and Communication Technology (ICT) and related application areas.

He was the Founder Chairman of the HERMES Partnership—a network of leading independent European research centers established in 1997, of which he is now the Honorary Chair. He is a Fellow of IEEE (USA), IETE (India), IET (UK), Wireless World Research Forum (WWRF) and a member of the Netherlands Electronics and Radio Society (NERG), and the Danish Engineering Society (IDA).

He has received Ridderkorset af Dannebrogordenen (Knight of the Dannebrog) in 2010 from the Danish Queen for the internationalization of top-class telecommunication research and education. He has been honored by the University of Rome “Tor Vergata,” Italy as Distinguished Professor of the Department of Clinical Sciences and Translational Medicine on March 15, 2016.

He has received several international awards as follows: IEEE Communications Society Wireless Communications Technical Committee Recognition Award in 2003 for making contribution in the field of “Personal, Wireless and Mobile Systems and Networks”; Telenor’s Research Award in 2005 for impressive merits, both academic and organizational within the field of wireless and personal communication; 2014 IEEE AESS Outstanding Organizational Leadership Award for “Organizational Leadership in developing and globalizing the CTIF (Center for TeleInFrastruktur) Research Network,” and so on.

He is the Founder Editor-in-Chief of the Springer International Journal on Wireless Personal Communications. He is a member of the editorial board of other renowned international journals including those of River Publishers. Ramjee Prasad is Founder Co-Chair of the steering committees of many renowned annual international conferences, e.g., Wireless Personal Multimedia Communications Symposium (WPMC); Wireless VITAE and Global Wireless Summit (GWS).

He has published more than 30 books, 1000 plus journal and conference publications, holds more than 15 patents, and has supervised over 100 Ph.D. graduates and larger number of masters (over 250). Several of his students are today worldwide telecommunication leaders themselves.



Dr. Sudhir Dixit is the CEO and a Co-Founder of Skydoot, Inc., a start-up in the content sharing and collaboration space. He is also a Fellow and Evangelist of Basic Internet at the Basic Internet Foundation in Norway. From December 2013 to April 2015, he was Distinguished Chief Technologist and CTO of the Communications and Media Services for the Americas Region of Hewlett-Packard Enterprise Services in Palo Alto, CA, and prior to this he was the Director of Hewlett-Packard Labs India from September 2009. From June 2009 to August 2009, he was Director at HP Labs in Palo Alto. Prior to joining HP Labs Palo Alto, Dixit held a joint appointment

with the Centre for Internet Excellence (CiE) and the Centre for Wireless Communications (CWC) at the University of Oulu, Finland. From 1996 to 2008, he held various positions with leading companies, such as with BlackBerry as Senior Director (2008), with Nokia and Nokia Networks in the United States as Senior Research Manager, Nokia Research Fellow, Head of Nokia Research Center (Boston), and Head of Network Technology (USA) (1996–2008). From 1987 to 1996, he was at NYNEX Science and Technology and GTE Laboratories (both now Verizon Communications) as Staff Director and Principal Research Scientist.

Sudhir Dixit has 21 patents granted by the US PTO and has published over 200 papers and edited, co-edited, or authored six books (Wi-Fi, WiMAX and LTE Multi-hop Mesh Networks by Wiley (2013), Globalization of Mobile and Wireless Communications by Springer (2011), Technologies for Home Networking by Wiley (2008), Content Networking in the Mobile Internet by Wiley (2004), IP over WDM by Wiley (2003), Wireless IP and Building the Mobile Internet by Artech House (2002)). He is presently on the editorial boards of IEEE Spectrum Magazine, Cambridge University Press Wireless Series, and Springer's Wireless Personal Communications Journal and Central European Journal of Computer Science (CEJS). He is Chairman of the Vision Committee and Vice Chair of the Americas region of the Wireless World Research Forum (WWRF). He also chairs the IEEE ComSoc Sub-Technical Committee on Fiber and Wireless Convergence.

From 2010 to 2012, he was Adjunct Professor of Computer Science at the University of California, Davis, and, since 2010, he has been Docent of Broadband Mobile Communications for Emerging Economies at the University of Oulu, Finland. A Fellow of the IEEE, IET, and IETE, Dixit received a Ph.D. degree in Electronic Science and Telecommunications from the University of Strathclyde, Glasgow, U.K. and an M.B.A. from the Florida Institute of Technology, Melbourne, Florida. He received his M.E. degree in Electronics Engineering from Birla Institute of Technology and Science, Pilani, India, and B.E. degree from Maulana Azad National Institute of Technology, Bhopal, India.

Abbreviations

3D	Three Dimensional
3GPP	3rd Generation Partnership Project
ABP	Arterial Blood Pressure
ADC	Analog-to-Digital Converter
ADPCM	Adaptive Differential Pulse Code Modulation
AFCRN	Absolute Radio Frequency Number
AI	Artificial Intelligence
AN	Access Node
ANN	Artificial Neural Network
AON	Active Optical Network
AP	Access Point
ARM	Association Rule Mining
BBU	Base-band Units
BD	Big Data
BLE	Bluetooth Low Energy
BM	Business Model
BMES	Business Model Ecosystems
BPSK	Binary Phase-Shift Keying
BS	Base Stations
CAD	Computer-Aided Design
CAPEX	Capital Expenditure
CD	Compact Disk
CDM	Code-Division Multiplexing
CDSS	Clinical Decision Support Systems
CELP	Code Excited Linear Predictive
CN	Core Network
CNSS	Communications Navigation Sensing and Services
COMSOC	Communications Society (IEEE)
COTS	Commercially off the shelf
CPS	Cyber-Physical Systems

CR	Cognitive Radio
C-RAN	Cloud Radio Access Networks
DB	Distributed Beamforming
DCR	Distant cognitive radio
E_b/N_0	Bit Energy-to-Noise Power Spectral Density Ratio
EC	European Commission
ECG	Electrocardiogram
EDGE	Enhanced Data rates for GSM Evolution
EEG	Electroencephalogram
EMR	Electronic Medical Records
ESPAR	Electronic Steerable Parasitic Antenna Array
FiWi	Fiber-Wireless
FPLMTS	Future Public Land Mobile Telecommunication Systems
FTTx	Fiber to the “x”
GDP	Gross Domestic Product
GPRS	General Packet Radio Service
GPS	Global Positioning System
GPU	Graphics Processing Unit
GSM	Global System for Mobile Communications
HBC	Human Bond Communication
HetNets	Heterogeneous Networks
HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
HVDC	High-Voltage Direct Current
ICD	International Classification of Diseases
ICT	Information and Communication Technologies
ICU	Intensive Care Unit
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	International Mobile Telecommunications-2000
IoE	Internet of Everything
IoS	Internet of Services
IoT	Internet of Things
IP	Intellectual Property
IS-54 (136)	Industry Standard-54 (136) (in USA)
ISM	Industrial Scientific Medical
ITS	Intelligent Transportation Systems
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
KPI	Key Performance Indicator
LINP	Logically Isolated Network Partitions
LMSC	LAN/MAN Standardization Committee
LNA	Low-Noise Amplifier
LoRa	L ow power long R ange
LP	Long Play

LTE	Long-Term Evolution
LTE-A	Long-Term Evolution Advanced
M2M	Machine 2 Machine
MIC	Mutual Information Coefficient
MIMIC	Multiparameter Intelligent Monitoring in Intensive Care
MIMO	Multiple Input–Multiple Output
MIT	Massachusetts Institute of Technology
MME	Mobility Management Entity
MtM	Machine-to-Machine
NFV	Network Function Virtualization
NGMN	Next-Generation Mobile Network
Ng-PON	Next-Generation Passive Optical Networks
NLP	Natural Language Processing
OAM&P	Operation, Administration, Maintenance, and Provisioning
OFDM	Orthogonal Frequency-Division Multiplexing
ONT	Optical Network Terminal
OPEX	Operational Expenditure
OSI	Open Systems Interconnection
OTT	Over the Top
PA	Power Amplifier
PAPR	Peak-to-Average Power Ratio
PCA	Principal Component Analysis
PGW	Packet Gateway
PHS	Personal Handy Phone System
PLL	Phase Lock Loop
PON	Passive Optical Network
PPG	Photoplethysmogram
PtP	Point-to-Point
PU	Primary User
QAM	Quadrature Axis Modulation
QoS	Quality of Service
R&D	Research & Development
RAN	Radio Access Network
RBM	Restricted Boltzmann Machine
RC	Radio Committee
RDBMS	Relational DataBase Management Systems
RF	Radio Frequency
RRU	Remote Radio Unit
SCM	Sub-Carrier Multiplexing
SDN	Software-Defined Networking
SDR	Software-Defined Radio
SGW	Serving Gateway
SISO	Single Input Single Output
SMNAT	Smart Mobile Network Access Topology
SON	Self-Organizing Networks