INTERNATIONAL STANDARD

ISO/IEC/IEEE 8802-15-4

Second edition
2018-03

Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements —

Part 15-4: Wireless medium access control (MAC) and physical layer (PHY) specifications for low-rate wireless personal area networks (WPANs)

Technologies de l'information — Télécommunications et échange d'information entre systèmes — Réseaux locaux et métropolitains — Exigences spécifiques —

Partie 15-4: Spécifications du contrôle d'accès du milieu sans fil (MAC) et de la couche physique (PHY) pour les réseaux personnels sans fil de faible débit (WPAN)

Reference number
ISO/IEC/IEEE 8802-15-4:2018(E)

COPYRIGHT PROTECTED DOCUMENT

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Institute of Electrical and Electronics Engineers, Inc
3 Park Avenue, New York
NY 10016-5997, USA

stds.ipr@ieee.org
www.ieee.org

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

The main task of ISO/IEC JTC 1 is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is called to the possibility that implementation of this standard may require the use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. ISO/IEEE is not responsible for identifying essential patents or patent claims for which a license may be required, for conducting inquiries into the legal validity or scope of patents or patent claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance or a Patent Statement and Licensing Declaration Form, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from ISO or the IEEE Standards Association.

ISO/IEC/IEEE 8802-15-4 was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE 802.15.4-2015). It was adopted by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems,* in parallel with its approval by the ISO/IEC national bodies, under the “fast-track procedure” defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE. IEEE is responsible for the maintenance of this document with participation and input from ISO/IEC national bodies.

This second edition cancels and replaces the first edition (ISO/IEC/IEEE 8802-15-4:2010), which has been technically revised.

A list of all parts in the ISO/IEC/IEEE 8802 series can be found on the ISO website.

IEEE Std 802.15.4™-2015
(Revision of
IEEE Std 802.15.4-2011)

IEEE Standard for Low-Rate Wireless Networks

Sponsor

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 5 December 2015

IEEE-SA Standards Board

Abstract: The protocol and compatible interconnection for data communication devices using low-data-rate, low-power, and low-complexity short-range radio frequency (RF) transmissions in a wireless personal area network (WPAN) are defined in this standard. A variety of physical layers (PHYs) have been defined that cover a wide variety of frequency bands.

Keywords: ad hoc network, IEEE 802.15.4™, low data rate, low power, LR-WPAN, mobility, PAN, personal area network, radio frequency, RF, short range, wireless, wireless personal area network, WPAN

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 978-1-5044-0854-5 STD20893
PDF: ISBN 978-1-5044-0846-2 STDPD20893

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Standards Documents."

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at http://ieeexplore.ieee.org/Xplore/home.jsp or contact IEEE at the address listed previously. For more information about the IEEE SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at http://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was sent to sponsor ballot, the IEEE P802.15 Working Group had the following voting members:

Robert F. Heile, *Chair*
Rick Alfvin, *Co-Vice Chair*
Patrick W. Kinney, *Co-Vice Chair*
James P. K. Gilb, *Working Group Technical Editor*
Patrick W. Kinney, *Secretary*

Patrick W. Kinney, *802.15 Maintenance Committee Chair*
Benjamin A. Rolfe, *802.15 Maintenance Committee Vice Chair*
James P. K. Gilb, *Technical Editor*

Mounir Achir
Keiji Akiyama
Arthur Astrin
Philip Beecher
Frederik Beer
Chandrashekhar P. S. Bhat
Kiran Bynam
Edgar Callaway
Chris Calvert
Radhakrishna Canchi
Kapseok Chang
Soo-Young Chang
Clint Chaplin
Stephen Chasko
Paul Chilton
Sangsung Choi
Hendricus de Ruijter
Guido Dolmans
Igor Dotlic
Stefan Drude
Dietmar Eggert
Shahriar Emami
Andrew Estrada
David Evans
George Flammer
Kiyoshi Fukui
Matthew Gillmore
Tim Godfrey
Elad Gottlib
Jussi Haapola
Rainer Hach
Shinsuke Hara
Timothy Harrington
James Hartman
Marco Hernandez
Ken Hiraga
Iwao Hosako
Yeong Min Jang
Seong-Soon Joo
Akifumi Kasamatsu
Shuzo Kato
Toyoyuki Kato
Jeritt Kent
Jaehwan Kim
Youngsoo Kim
Shoichi Kitazawa
Tero Kivinen
Ryuji Kohno
Fumihide Kojima
Thomas Kuerner
Byung-Jae Kwak
Jae Seung Lee
Myung Lee
Sangjae Lee
Huan-Bang Li
Liang Li
Qing Li
Michael Lynch
Itaru Maekawa
Hiroyuki Matsumura
Michael McLaughlin
Michael McInnis
Kenichi Mori
Robert Moskowitz
Jinesh P. Nair
Chiu Ngo
Paul Nikolich
John Notor
Hiroyo Ogawa
Taejoon Park
Glenn Parsons
Charles Perkins
Albert Petrick
Clinton C. Powell
Verotiana Rabarijaona
Ivan Reede
Richard Roberts
Ruben E. Salazar Cardozo
Noriyuki Sato
Norihiko Sekine
Kunal Shah
Stephen Shellhammer
Shusaku Shimada
Gary Stuebing
Don Sturek
Mineo Takai
Kou Togashi
Billy Verso
Gabriel Villardi
Brian Weis
Makoto Yaita
Peter Yee
Yu Zeng
Chunhui (Allan) Zhu

Major contributions in the revision process were received from the following individuals:

Philip Beecher
Monique Brown
Edgar Callaway
Soo-Young Chang
James P. K. Gilb
Tim Godfrey
Jussi Haapola
Timothy Harrington
Jeritt Kent
Patrick W. Kinney
Tero Kivinen
Amarjeet Kumar
Michael McInnis
Robert Moskowitz
Clinton C. Powell
Verotiana Rabarijaona
Benjamin A. Rolfe
Ruben E. Salazar Cardozo
Cristina Seibert
Kunal Shal
Shusakh Shimada
Chin-Sean Sum
Larry Taylor
Billy Verso

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Rick Alfvin
Nobumitsu Amachi
Butch Anton
Stefan Aust
Michael Bahr
Madhusudan Banavara
Philip E. Beecher
Harry Bims
Gennaro Boggia
Riccardo Brama
Nancy Bravin
Vern Brethour
Monique Brown
William Byrd
Brent Cain
Edgar Callaway
Radhakrishna Canchi
Juan Carreon
Suresh Channarasappa
Keith Chow
Charles Cook
Steven Crowley
Sourav Dutta
Richard Edgar
David Evans
Liu Fangfang
Michael Fischer
Avraham Freedman
Devon Gayle
James P. K. Gilb
Gregory Gillooly
Joel Goergen
Randall Groves
Chris Guy
Rainer Hach
Timothy Harrington
Marco Hernandez
Guido Hiertz
Werner Hoelzl
Tetsushi Ikegami
Noriyuki Ikeuchi
Akio Iso
Atsushi Ito
Raj Jain
Oyvind Janbu
Michael Johas Teener
Adri Jovin
Naveen Kakani
Shinkyo Kaku
Piotr Karocki
Ruediger Kays
Jeritt Kent
Stuart Kerry
Yongbum Kim
Patrick W. Kinney
Tero Kivinen
Fumihide Kojima
Bruce Kraemer
Yasushi Kudoh
Amarjeet Kumar
Jeremy Landt
Hyeong Ho Lee
James Lepp
Arthur H. Light
Vincent Lipsio
William Lumpkins
Elvis Maculuba
James Marin
Roger Marks
Michael McInnis
Michael McLaughlin
Apurva Mody
Jose Morales
Ronald Murias
Jinesh Nair
Juichi Nakada
Michael Newman
Chiu Ngo
Nick S. A. Nikjoo
Paul Nikolich
Yoshihiro Ohba
Okundu Omeni
Satoshi Oyama
Stephen Palm
Arumugam Paventhan
Dalibor Pokrajac
Clinton C. Powell
Venkatesha Prasad
Verotiana Rabarijaona
Demir Rakanovic
R. K. Rannow
Maximilian Riegel
Robert Robinson
Osman Sakr
Ruben E. Salazar Cardozo
John Santhoff
Naotaka Sato
Bartien Sayogo
Kunal Shah
Shusaku Shimada
Suresh Shrimavle
Daniel Smolinski
Thomas Starai
Rene Struik
Walter Struppler
Patricia Thaler
David Thompson
Ha-Nguyen Tran
Mark-Rene Uchida
Lorenzo Vangelista
Dmitri Varsanofiev
Prabodh Varshney
Raj Vaswani
George Vlantis
Khurram Waheed
Hung-Yu Wei
Brian Weis
Andreas Wolf
Oren Yuen
Daidi Zhong

When the IEEE-SA Standards Board approved this standard on 5 December 2015, it had the following membership:

John Kulick, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi
Ted Burse
Stephen Dukes
Jean-Phillippe Faure
J. Travis Griffith
Gary Hoffman
Michael Janezic
Joseph L. Koepfinger*
David J. Law
Hung Ling
Andrew Myles
T. W. Olsen
Glenn Parsons
Ronald C. Peterson
Annette D. Reilly
Stephen J. Shellhammer
Adrian P. Stephens
Yatin Trivedi
Phillip Winston
Don Wright
Yu Yuan
Daidi Zhong

*Member Emeritus

Historical participants

Many individuals have participated in the IEEE P802.15 Working Group during various stages of the standard's development. Since the initial publication, many amendments have added functionality or updated material in this standard, and now three revisions have been published. Here is a historical list of the working group participants who dedicated their valuable time, energy, and knowledge to the advancement of this standard at the time of its original publication and for its revisions. Many of these members also worked on amendments.

The following members of the IEEE P802.15 Working Group participated in the development of the original standard, IEEE Std 802.15.4-2003:

Robert F. Heile, *Chair*
James D. Allen, *Vice Chair*
Patrick W. Kinney, *Secretary*
Michael D. McInnis, *Assistant Secretary and Editor*

Ian C. Gifford, *Task Group 1 Chair*
Stephen J. Shellhammer, *Task Group 2 Chair*
John R. Barr, *Task Group 3 Chair*

Patrick W. Kinney, *Task Group 4 Chair*
Phil Jamieson, *Task Group 4 Vice Chair*
José A. Gutierrez, *Task Group 4 Editor-in-Chief*
Marco Naeve, *Task Group 4 Secretary*

Monique Bourgeois, *MAC Technical Editor*
Said Moridi, *PHY Technical Editor*
Phil Jamieson, *Layer Management Technical Editor*
Greg Breen, *Low-Band PHY Technical Editing*
Ed Callaway, *Networking Technical Editing*
Paul Gorday, *High-Band PHY Technical Editing*
Marco Naeve, *General Description Technical Editing*
David Cypher, *PICs/SDLs Technical Editing*
Robert D. Poor, *Coexistence Technical Editing*
Farron Dacus, *Regulatory Technical Editing*

Roberto Aiello
Masaaki Akahane
Richard Alfvin
Arun Arunachalam
Naiel Askar
Venkat I. Bahl
Daniel Bailey
Jay Bain
James Baker
Jaiganesh Balakrishnan
Anuj Batra
Timothy Blaney
Kenneth Boehike
Stan Bottoms
Mark V. Bowles
Chuck Brabenac
Soo-Young Chang
Francois Po_Shin Chin
Aik Chindapol
Craig Conkling
Anand Dabak
Kai Dombrowski
Mary DuVal
Michael Dydyk
Jason L. Ellis
Mark W. Fidler
Jeff R. Foerster
David S. Furuno
Pierre Gandolfo
Atul Garg
James Gilb
Nada Golmie
Yasuo Harada
Allen Heberling
Barry Herold
Robert Y. Huang
Eran Igler
Katsumi Ishii
Jeyhan Karaoguz
Masami Katagiri
Joy H. Kelly
Stuart J. Kerry
Yongsuk Kim
Young Hwan Kim
Günter Kleindl
Bruce P. Kraemer
DoHoon Kwon
Jim Lansford
David Leeper
Liang Li
Yeong-Chang Maa
Steven March
Ralph Mason
Jim Meyer
Leonard E. Miller
Akira Miura
Andreas Molisch

Antonio Mondragon
Tony Morelli
Chiu Ngo
Kei Obara
Knut Odman
John B. Pardee
Jongun Park
Dave Patton
Marcus Pendergrass
Gregg Rasor
Ivan Reede
Jim Richards
Glyn Roberts
Richard Roberts
William Roberts
Chris Rogers
Philippe Rouzet
Chandos Rypinski
John H. Santhoff
Mark Schrader
Tom Schuster
Erik Schylander
Michael Seals
Nick Shepherd
Gadi Shor
William Shvodian
Thomas Siep
Kazimierz Siwiak
Carl Stevenson
Rene Struik
Shigeru Sugaya
Kazuhisa Takamura
Katsumi Takaoka
Teik-Kheong Tan
Larry Taylor
Stephen E. Taylor
Hans vanLeeuwen
Ritesh Vishwakarma
Thierry Walrant
Jing Wang
Fijio Watanabe
Mathew Welborn
Richard Wilson
Stephen Wood
Edward G. Woodrow
Hirohisa Yamaguchi
Amos Young
Song-Lin Young
Nakache Yves-paul
Jim Zyren

Major contributions were received from the following individuals:

Tony Adamson
David Archer
David Avery
Venkat Bahl
Daniel Bailey
Edul Batliwala
Pratik Bose
Boaz Carmeli
Farron Dacus
Martin Digon
Ian C. Gifford
Ed Hogervorst
Stephen Korfhage
Charles Luebke
Masahiro Maeda
Ian Marsden
Chris Marshall
Paul Marshall
Fred Martin
Ralph Mason
Rod Miller
Phil Rudland
Niels Schutten
Nick Shepherd
Ari Singer
Ralph D'Souza
Carl Stevenson
Mark Tilinghast
Hans Van Leeuwen
Jacco van Muiswinkel
Luis Pereira
Richard Wilson
Wim Zwart

The following members of the IEEE P802.15 Working Group participated in the development of the first revision, IEEE Std 802.15.4-2006:

Robert F. Heile, *Chair*
James D. Allen, *Vice Chair*
Patrick W. Kinney, *Assistant Vice Chair*
James P. K. Gilb, *Editor-in-Chief*
Patrick W. Kinney, *Secretary*
Michael D. McInnis, *Assistant Secretary and Editor*

John R. Barr, *Task Group 3b Chair*
Reed Fisher, *Task Group 3c Chair*
Patrick W. Kinney, *Task Group 4a Chair*
Myung Lee, *Task Group 5 Chair*

Robert D. Poor, *Task Group 4b Chair*
Marco Naeve, *Task Group 4b Vice Chair*
Monique B. Brown, *Task Group 4b Editor-in-Chief*
Eric T. Gnoske, *Task Group 4b Secretary*

Philip E. Beecher, *MAC Contributing Editor*
Monique B. Brown, *MAC Technical Editor*
Edgar H. Callaway, Jr., *MAC Contributing Editor*
Francois Chin, *PHY Contributing Editor*
Robert C. Cragie, *MAC/Security Contributing Editor*

Paul Gorday, *PHY Contributing Editor*
James P. K. Gilb, *Draft D3 Editor-in-Chief*
Øyvind Janbu, *MAC/PHY/Security Contributing Editor*
Marco Naeve, *General Description/PICS Editor, MAC Contributing Editor*
Clinton C. Powell, *PHY Technical Editor*
Joseph Reddy, *Security Contributing Editor*
Zachary Smith, *MAC Contributing Editor*
René Struik, *Security Contributing Editor*
Andreas C. Wolf, *PHY Contributing Editor*

Roberto Aiello
Richard Alfvin
Mikio Aoki
Takashi Arita
Larry Arnett
Arthur Astrin
Yasaman Bahreini
Jay Bain
Alan Berkema
Bruce Bosco
Mark Bowles
Charles Brabenac
David Brenner
Vern Brethour
Ronald Brown
Bill Carney
Kuor-Hsin Chang
Jonathon Cheah
Kwan-Wu Chin
Sarm-Goo Cho
Sungsoo Choi
Yun Choi
Chun-Ting Chou
Manoj Choudhary
Celestino Corral
Joe Decuir
Javier Del Prado Pavon
Kai Dombrowski
Stefan Drude
Amal Ekbal
Jason Ellis
Shahriar Emami
Paul Everest
Mark W. Fidler
Kris Fleming
Amir Freund
Camillo Gentile
Ian Gifford
Sung-Wook Goh
Sorin Goldenberg
Vivek Gupta
Rainer Hach
Robert Hall
Shinsuke Hara
Jeff Harris
Allen Heberling
Eric Heinze
Barry Herold
Keisuke Higuchi
Jin-Meng Ho
Patrick Houghton
Robert Huang
Tian-Wei Huang
Hideto Ikeda
Tetsushi Ikegami
Adrian Jennings
Ho-In Jeon
Tzyy Hong Jiang
David Julian
Jeyhan Karaoguz
Michael Kelly
Stuart Kerry
Jae-Hyon Kim
Jaeyoung Kim
Jinkyeong Kim
Yongsuk Kim
Kursat Kimyacioglu
Matthias Kindler
Guenter Kleindl
Ryuji Kohno
Mike Krell
Yasushi Kudo
Akiomi Kunisa
Yuzo Kuramochi
Jiun-You Lai
Ismail Lakkis
John Lampe
Kyung Kuk Lee
Wooyong Lee
David Leeper
Huan-Bang Li
Haixiang Liang
Ian Macnamara
Akira Maeki
Patricia Martigne
Abbie Mathew
Taisuke Matsumoto
Gustaf Max
Michael McLaughlin
Charlie Mellone
Klaus Meyer
Samuel Mo
Andreas Molisch
Mark Moore
Ken Naganuma
Yves-Paul Nakache
Hiroyuki Nakase
Saishankar Nandagopalan
Chiu Ngo
Erwin Noble
John O'Conor
Knut Odman
Hiroyo Ogawa
Yasuyuki Okuma
Philip Orlik
Laurent Ouvry
John Pardee
Nirmalendu Patra
Dave Patton
Xiaoming Peng
Tony Pollock
Vidyasagar Premkumar
Yihong Qi
Raad Raad
Pekka Ranta
Dani Raphaeli
Gregg Rasor
Charles Razzell
Ivan Reede
Yuko Rikuta
Terry Robar
Glyn Roberts
Richard Roberts
Benjamin A. Rolfe
Philippe Rouzet
Chandos Rypinski
Ali Sadri
Saeid Safavi
Zafer Sahinoglu
Tomoki Saito
Syed Saleem
Kamran Sayrafian
Jean Schwoerer
Erik Schylander
Alireza Seyedi
Sanjeev Sharma
Siddharth Shetty
John Shi
Shusaku Shimada
Yuichi Shiraki
Gadi Shor
William Shvodian
Thomas Siep
Michael Sim
Kazimierz Siwiak
V. Somayazulu
Amjad Soomro
Carl Stevenson
Kazuaki Takahashi
Kenichi Takizawa
Teik-Kheong Tan
Mike Tanahashi
Yasushi Tanaka
James Taylor
Arnaud Tonnerre
Ichihiko Toyoda

Jerry Upton
Bart Van Poucke
Chris Weber
Matthew Welborn
Magnus Wiklund
Gerald Wineinger
Patrick Worfolk
Tracy Wright
Hirohisa Yamaguchi
Kamya Yekeh Yazdandoost
Su-Khiong Yong
Zhan Yu
Serdar Yurdakul
Mahmoud Zadeh
Bin Zhen

Major contributions in the revision process were received from the following individuals:

Jon Adams
Helmut P. Adamski
Jonathan Avey
Jon Beniston
Bernd Grohmann
José A. Gutierrez
Jesper Holm
ZhiJian Hu
Phil A. Jamieson
Yuen-Sam Kwok
Colin Lanzl
Myung Lee
Zhongding Lei
Liang Li
Yong Liu
Frederick Martin
Frank Poegel
Matthias Scheide
D. C. Seward
Huai-Rong Shao
Mark Shea
Stephen J. Shellhammer
Mark A. Tillinghast
Johannes Van Leeuwen
Richard Wilson
Ping Xiong
Bing Xu
ChenYang Yang
Chunhui Zhu

The following members of the IEEE P802.15 Working Group participated in the development of the second revision, IEEE Std 802.15.4-2011:

Robert F. Heile, *Chair*
Rick Alfvin, *Co-Vice Chair*
Patrick W. Kinney, *Co-Vice Chair*
James P. K. Gilb, *Working Group Technical Editor*
Patrick W. Kinney, *Secretary*

James P. K. Gilb, *Task Group 4i Chair and Technical Editor*

Emad Afifi
Gahng-Seop Ahn
Roberto Aiello
Arthur Astrin
Taehan Bae
Michael Bahr
John Barr
Anuj Batra
Tuncer Baykas
Philip E. Beecher
Ashutosh Bhatia
Ghulam Bhatti
Gary Birk
Mathew Boytim
Peter David Bradley
Nancy Bravin
David Britz
Monique B. Brown
Sverre Brubk
Brian Buchanan
John Buffington
Kiran Bynam
Brent Cain
Edgar H. Callaway
Chris Calvert
Ruben E. Salazar Cardozo
Douglas Castor
Jaesang Cha
Russell Chandler
Kuor-Hsin Chang
Soo-Young Chang
Clint Chaplin
Hind Chebbo
Chang-Soon Choi
Sangsung Choi
Ciaran Connell
David Cypher
Matthew Dahl
David Davenport
Mark Dawkins
Hendricus de Ruijter
Upkar Dhaliwal
Gang Ding
Paul Dixon
Guido Dolmans
Igor Dotlic
Michael Dow
Dietmar Eggert
David Evans
Charles Farlow
John Farserotu
Jeffrey Fischbeck
Mike Fischer
George Flammer
Ryosuke Fujiwara
Noriyasu Fukatsu
Kiyoshi Fukui
John Geiger
Gregory Gillooly
Tim Godfrey
Paul Gorday
Elad Gottlib
Robert Hall
Shinsuke Hara
Hiroshi Harada
Timothy Harrington
Rodney Hemminger
Marco Hernandez
Garth Hillman
Jin-Meng Ho
Wei Hong
Srinath Hosur
David Howard
Jung-Hwan Hwang
Taeho Hwang

Ichirou Ida
Tetsushi Ikegami
Akio Iso
Yeong Min Jang
Adrian Jennings
Wuncheol Jeong
Steven Jillings
Noh-Gyoung Kang
Tae-Gyu Kang
Shuzo Kato
Tatsuya Kato
Jeritt Kent
Prithpal Khakuria
Dae Ho Kim
Dong-Sun Kim
Dukhyun Kim
Jaehwan Kim
Jeffrey King
Ryuji Kohno
Fumihide Kojima
Bruce Kraemer
Raymond Krasinski
Masahiro Kuroda
John Lampe
Zhou Lan
Khanh Le
Cheolhyo Lee
Hyungsoo Lee
Myung Lee
Daniel Lewis
Huan-Bang Li
Liang Li
Sang-Kyu Lim
Jeremy Link
Mike Lynch
Robert Mason
Tomokuni Matsumura
Jeff McCullough
Michael McGillan
Michael D. McInnis
Michael McLaughlin
Charles Millet
Siamak Mirnezami
Rishi Mohindra
Emmanuel Monnerie
Rajendra Moorti
Robert Moskowitz
Hamilton Moy
Peter Murray
Theodore Myers
Chiu Ngo
Paul Nikolich
Hirohito Nishiyama
David Olson
Okundu Omeni
Ryoji Ono
Laurent Ouvry
James Pace
Hyung-Il Park
Jahng Park
Seung-Hoon Park
Taejoon Park
Ranjeet Patro
Al Petrick
Dalibor Pokrajac
Daniel Popa
Stephen Pope
Clinton C. Powell
Richard Powell
Chang-Woo Pyo
Mohammad Rahman
Sridhar Rajagopal
Jayaram Ramasastry
Marc Reed
Ivan Reede
Richard Roberts
Craig Rodine
June Chul Roh
Benjamin A. Rolfe
Seung-Moon Ryu
Didier Sagan
Kentaro Sakamoto
Will San Filippo
H. Sanderford
Kamran Sayrafian
Timothy Schmidl
Michael Schmidt
Jean Schwoerer
Cristina Seibert
Neal Seidl
Kunal Shah
Steve Shearer
Stephen Shellhammer
Shusaku Shimada
Chang Sub Shin
Cheol Ho Shin
Michael Sim
Jonathan Simon
Jaeseung Son
Paul Stadnik
René Struik
Chin-Sean Sum
Hui-Hsia Sung
Gu Sungi
Kenichi Takizawa
Hirokazu Tanaka
Larry Taylor
Mark Thompson
James Tomcik
Ichihiko Toyoda
David Tracey
Khanh Tran
Jerry Upton
Jana van Greunen
Hartman van Wyk
Michel Veillette
Billy Verso
Bhupender Virk
Joachim Walewski
Junyi Wang
Quan Wang
Xiang Wang
Andy Ward
Scott Weikel
Nicholas West
Mark Wilbur
Ludwig Winkel
Eun Tae Won
Alan Chi Wai Wong
Tao Xing
Wen-Bin Yang
Yang Yang
Kazuyuki Yasukawa
Kamya Yazdandoost
Kaoru Yokoo
Mu Zhao
Bin Zhen

Major contributions in the revision process were received from the following individuals:

Philip E. Beecher
Vern Brethour
Monique B. Brown
Edgar H. Callaway
Kuor-Hsin Chang
Clint Chaplin
James P. K. Gilb
Patrick W. Kinney
Michael D. McInnis
Clinton C. Powell
Benjamin A. Rolfe
Timothy Schmidl
René Struik
Billy Verso

Introduction

This introduction is not part of IEEE Std 802.15.4™-2015, IEEE Standard for Low-Rate Wireless Networks.

This is the third revision of IEEE Std 802.15.4. From the beginning, the goal of the IEEE P802.15 Working Group was to produce a standard that enabled very low-cost, low-power communications. The initial standard, IEEE Std 802.15.4-2003, defined two optional physical layers (PHYs), operating in different frequency bands with a simple and effective medium access control (MAC).

In 2006, the standard was revised and added two more PHY options. The MAC remained backward compatible, but the revision added MAC frames with an increased version number and a variety of MAC enhancements, including the following:

— Support for a shared time base with a data time stamping mechanism
— Support for beacon scheduling
— Synchronization of broadcast messages in beacon-enabled personal area networks (PANs)
— Improved MAC layer security

In 2011, the standard was revised to include the three amendments approved subsequent to the 2006 revision. This effort added four more PHY options along with the MAC capability to support ranging. Additionally, the organization of the standard was changed so that each PHY would have a separate clause, and the MAC clause was split into functional description, interface specification, and security specification.

The current revision of the standard was created to roll in the amendments approved subsequent to the 2011 revision: six PHY amendments and one MAC amendment, with corrigenda and clarifications. The features added by the amendments include the following:

— Enhanced frame formats maintaining backward compatibility
— Information Elements (IEs)
— Channel agility
— Extended superframe options
— Low-energy mechanisms
— An enhanced acknowledgment frame that can carry data and can be secured
— Prioritized channel access
— A variety of new PHY modulation, coding, and band options to support a wide variety of application needs including radio frequency identification (RFID), smart utility networks (SUNs), television white space (TVWS) operation, low-energy critical infrastructure monitoring (LECIM), and rail communications and control (RCC).

Much of the corrigenda and clarifications were collected from requests from individuals after the revision in 2011. Major corrigenda items included changes to the security text to correct errors and clarify the text, removal of the encrypt only mode, addition of security policy checks for the IEs, corrections regarding personal area network identifier (PAN ID) compression behavior to eliminate ambiguous specification, and changes to the IEs subclauses to include more information necessary for users of this standard.

The Project Authorization Request (PAR) for IEEE Std 802.15.4-2015 was first proposed in July 2013 and was approved in October 2013 by IEEE's New Standards Committee (NesCom). After three working group ballots and two sponsor ballots, the final standard was approved in December 2015, just over two years from start to finish.

Contents

IEEE Standard for Low-Rate Wireless Networks

1. Overview

1.1 Scope

This standard defines the physical layer (PHY) and medium access control (MAC) sublayer specifications for low-data-rate wireless connectivity with fixed, portable, and moving devices with no battery or very limited battery consumption requirements. In addition, the standard provides modes that allow for precision ranging. PHYs are defined for devices operating various license-free bands in a variety of geographic regions.

1.2 Purpose

The standard provides for ultra low complexity, ultra low cost, ultra low power consumption, and low data rate wireless connectivity among inexpensive devices. In addition, one of the alternate PHYs provides precision ranging capability that is accurate to one meter. Multiple PHYs are defined to support a variety of frequency bands.