IEEE STANDARDS ASSOCIATION

IEEE Standard for Low-Rate Wireless Networks

Amendment 7: Defining Enhancements to the Smart Utility Network (SUN) Physical Layers (PHYs) Supporting up to 2.4 Mb/s Data Rates

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 802.15.4x™-2019
(Amendment toIEEE Std 802.15.4™-2015
as amended by IEEE Std 802.15.4n™-2016,
IEEE Std 802.15.4q™-2016, IEEE Std 802.15.4u™-2016,
IEEE Std 802.15.4t™-2017, IEEE Std 802.15.4v™-2017,
IEEE Std 802.15.4s™-2018, and IEEE Std 802.15.4-2015/Cor 1-2018)

IEEE Std 802.15.4x™-2019
(Amendment to IEEE Std 802.15.4™-2015
as amended by IEEE Std 802.15.4n™-2016,
IEEE Std 802.15.4q™-2016, IEEE Std 802.15.4u™-2016,
IEEE Std 802.15.4t™-2017, IEEE Std 802.15.4v™-2017,
IEEE Std 802.15.4s™-2018, and IEEE Std 802.15.4-2015/Cor. 1-2018)

IEEE Standard for Low-Rate Wireless Networks

Amendment 7: Defining Enhancements to the Smart Utility Network (SUN) Physical Layers (PHYs) Supporting up to 2.4 Mb/s Data Rates

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 21 March 2019

IEEE-SA Standards Board

Abstract: Enhancements to the IEEE 802.15.4™ smart utility network (SUN) orthogonal frequency division multiplexing (OFDM) physical layers (PHYs) that enable support for data rates up to 2.4 Mb/s are defined by this amendment to IEEE Std 802.15.4™-2015. This amendment also defines additional channel plans, as needed, to support emerging applications.

Keywords: amendment, IEEE 802.15.4™, IEEE 802.15.4x™, low data rate, low power, wireless personal area network, WPAN

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

PDF: ISBN 978-1-5044-5673-9 STD23621
Print: ISBN 978-1-5044-5674-6 STDPD23621

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 Notices and Disclaimers Concerning IEEE Standards Documents." They can also be obtained on request from IEEE or viewed at http://standards.ieee.org/ipr/disclaimers.html.

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. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups 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 Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

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. A current 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 IEEE Xplore at http://ieeexplore.ieee.org/ 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 submitted to the IEEE-SA Standards Board for approval, the Wireless Personal Area Network (WPAN) Working Group had the following membership:

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

Matt Gillmore, *Task Group 4x Chair*
Kunal Shah, *Task Group 4x Vice-Chair and Technical Editor*
Chris Calvert, *Task Group 4x Technical Editor*

Hendrik Ahlendorf
Koorosh Akhavan
Bernd Baer
David Barras
Tuncer Baykas
Philip Beecher
Friedbert Berens
Monique Brown
Radhakrishna Canchi
Jaesang Cha
Matthew Chang
Soo-Young Chang
Clint Chaplin
Boris Danev
Luc Darmon
Hendricus De Ruijter
Brandon Dewberry
Anthony Fagan
Tim Godfrey
Jianlin Guo
Joachim Hammerschmidt
Chong Han
Shinsuke Hara
Hiroshi Harada
Timothy Harrington
Chris Hartman
Christopher Hett
Jay Holcomb
Iwao Hosako
Brima Ibrahim
Tetsushi Ikegami
Yeong Min Jang
Seongah Jeong
Seong-Soon Joo
Volker Jungnickel
S. G. Karthik
Paul Kettle
Shoichi Kitazawa
Tero Kivinen
Daniel Knobloch
Ryuji Kohno
Fumihide Kojima
Ann Krieger
Thomas Kuerner
Jack Lee
Frank Leong
Huan-Bang Li
Qiang Li
Zheda Li
Sang-Kyu Lim
Thomas Lorbach
Masood Maqbool
Vinayagam Mariappan
Alejandro Marquez
Michael McInnis
Ayman Naguib
Jaroslaw Niewczas
Paul Nikolich
Mohammad Noshad
Aditya V. Padaki
Taejoon Park
Glenn Parsons
Charles Perkins
Albert Petrick
Joe Polland
Clinton Powell
Demir Rakanovic
Ivan Reede
Joerg Robert
Richard Roberts
Ren Sakata
Ruben E. Salazar Cardozo
Ioannis Sarris
Peter Sauer
Nikola Serafimovski
Tushar Shah
Stephen Shellhammer
Gary Stuebing
Don Sturek
Billy Verso
Xu Wang
Johannes Wechsler
Brian Weis
Hidetoshi Yokota

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

Thomas Alexander
Rick Alfvin
Butch Anton
Stefan Aust
Harry Bims
Riccardo Brama
Nancy Bravin
Vern Brethour
Demetrio Bucaneg
William Byrd
Brent Cain
Edgar Callaway
Keith Chow
Steven Crowley
Liu Fangfang
Avraham Freedman
Yukihiro Fujimoto
James P. K. Gilb
Matt Gillmore
Randall Groves
Timothy Harrington
Marco Hernandez
Werner Hoelzl
Noriyuki Ikeuchi
Sergiu Iordanescu
Atsushi Ito
Raj Jain
Sangkwon Jeong
Piotr Karocki
Stuart Kerry

Evgeny Khorov
Yongbum Kim
Tero Kivinen
Yasushi Kudoh
Hyeong Ho Lee
Elvis Maculuba
Vinayagam Mariappan
Stephen McCann
Richard Mellitz
Michael Newman
Nick S. A. Nikjoo
Paul Nikolich
Tetsu Nishimura
Satoshi Oyama
Bansi Patel
Arumugam Paventhan
Clinton Powell
Venkatesha Prasad
R. K. Rannow
Maximilian Riegel
Shigenobu Sasaki
Naotaka Sato
Kunal Shah
Daniel Smith
Thomas Starai
Walter Struppler
Don Sturek
Mark Sturza
Ganesh Subramanian
Mark-Rene Uchida
Dmitri Varsanofiev
George Vlantis
Lisa Ward
Karl Weber
Hung-Yu Wei
Scott Willy
Oren Yuen

When the IEEE-SA Standards Board approved this standard on 21 March 2019, it had the following membership:

Gary Hoffman, *Chair*
Ted Burse, *Vice Chair*
Jean-Philippe Faure, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi
Stephen D. Dukes
J. Travis Griffith
Guido Hiertz
Christel Hunter
Joseph L. Koepfinger*
Thomas Koshy
John D. Kulick
David J. Law
Joseph Levy
Howard Li
Xiaohui Liu
Kevin Lu
Daleep Mohla
Andrew Myles
Annette D. Reilly
Dorothy Stanley
Sha Wei
Phil Wennblom
Philip Winston
Howard Wolfman
Feng Wu
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.15.4x-2019, IEEE Standard for Low-Rate Wireless Networks—Amendment 7: Defining Enhancements to the Smart Utility Network (SUN) Physical Layers (PHYs) Supporting up to 2.4 Mb/s Data Rates.

This amendment defines enhancements to the IEEE 802.15.4 smart utility network (SUN) orthogonal frequency division multiplexing (OFDM) physical layers (PHYs) that enable support for data rates up to 2.4 Mb/s. This amendment also defines additional channel plans, as needed, to support emerging applications.

Building upon the numerous successful deployments of the IEEE 802.15.4 SUN PHY technology in field area networking (FAN) and the rapid growth in applications, such as the Internet of Things (IoT), Smart Grid, Smart Cities, and others, these SUN PHY enhancements are needed to support higher data rates along with enhancements for longer range utilizing existing hardware deployments based upon the IEEE 802.15.4 SUN PHYs. As an example, these enhancements enable broader electric system distribution automation and reduce the amount of equipment needed for deployment in Smart Grid systems. This example is but one of many application areas where FAN enhancements can have a substantial beneficial impact.

Contents

IEEE Standard for Low-Rate Wireless Networks

Amendment 7: Defining Enhancements to the Smart Utility Network (SUN) Physical Layers (PHYs) Supporting up to 2.4 Mb/s Data Rates

(This amendment is based on IEEE Std 802.15.4™-2015 as amended by IEEE Std 802.15.4n™-2016, IEEE Std 802.15.4q™-2016, IEEE Std 802.15.4u™-2016, IEEE Std 802.15.4t™-2017, IEEE Std 802.15.4v™-2017, IEEE Std 802.15.4s™-2018, and IEEE Std 802.15.4-2015/Cor. 1-2018.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.[1]

[1] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.