

**IEEE Standard for Information Technology—
Telecommunications and Information Exchange between Systems
Local and Metropolitan Area Networks—
Specific Requirements**

**Part 11: Wireless LAN Medium Access Control
(MAC) and Physical Layer (PHY) Specifications**

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

IEEE Std 802.11™-2020
(Revision of IEEE Std 802.11-2016)

**IEEE Standard for Information Technology—
Telecommunications and Information Exchange between Systems
Local and Metropolitan Area Networks—
Specific Requirements**

**Part 11: Wireless LAN Medium Access Control
(MAC) and Physical Layer (PHY) Specifications**

Developed by the
LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 3 December 2020
IEEE SA Standards Board

Abstract: Technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions are specified in this revision. Amendments 1 to 5 published in 2016 and 2018 have also been incorporated into this revision.

Keywords: 2.4 GHz, 256-QAM, 3650 MHz, 4.9 GHz, 5 GHz, 5.9 GHz, 60 GHz, advanced encryption standard, AES, audio, beamforming, carrier sense multiple access/collision avoidance, CCMP, channel switching, clustering, contention based access period, Counter mode with Cipher-block chaining Message authentication code Protocol, confidentiality, CSMA/CA, DFS, direct link, directional multi-gigabit, dynamic allocation of service period, dynamic extension of service period, dynamic frequency selection, dynamic truncation of service period, E911, EDCA, emergency alert system, emergency services, fast session transfer, forwarding, GCMP, generic advertisement service, high throughput, IEEE 802.11™, international roaming, interworking, interworking with external networks, LAN, local area network, MAC, management, measurement, medium access control, media-independent handover, medium access controller, mesh, MIS, millimeter-wave, MIMO, MIMO-OFDM, multi-band operation, multi-hop, multi-user MIMO, multiple input multiple output, network advertisement, network discovery, network management, network selection, noncontiguous frequency segments, OCB, path-selection, personal basic service set, PHY, physical layer, power saving, QoS, quality of service, quality-of-service management frame, radio, radio frequency, RF, radio resource, radio management, relay operation, spatial sharing, SSPN, subscriber service provider, television white spaces, TPC, transmit power control, video, wireless access in vehicular environments, wireless LAN, wireless local area network, WLAN, wireless network management, zero-knowledge proof

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

Copyright © 2021 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 26 February 2021. Printed in the United States of America.

IEEE and 802 are registered trademarks in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

Print: ISBN 978-1-5044-7283-8 STD24548
PDF: ISBN 978-1-5044-7284-5 STD24548

IEEE prohibits discrimination, harassment and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE Standards documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page (<https://standards.ieee.org/ipr/disclaimers.html>), appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

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

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE SA) Standards Board. IEEE develops its standards through an accredited consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed by volunteers with scientific, academic, and industry-based expertise in technical working groups. Volunteers are not necessarily members of IEEE or IEEE SA, 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 makes no warranties or representations concerning its standards, and expressly disclaims all warranties, express or implied, concerning this standard, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. In addition, IEEE does not warrant or represent that the use of the material contained in its standards is free from patent infringement. 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: THE NEED TO PROCURE 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 is 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, nor 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 the presenter's views should be considered the personal views of that individual rather than the formal position of IEEE, IEEE SA, the Standards Committee, or the Working Group.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE or IEEE SA. However, **IEEE does not provide interpretations, 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 evaluating comments or in revisions to an IEEE standard is welcome to join the relevant IEEE working group. You can indicate interest in a working group using the Interests tab in the Manage Profile & Interests area of the [IEEE SA myProject system](#). An IEEE Account is needed to access the application.

Comments on standards should be submitted using the [Contact Us](#) form.

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 constitute 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.

Data privacy

Users of IEEE Standards documents should evaluate the standards for considerations of data privacy and data ownership in the context of assessing and using the standards in compliance with applicable laws and regulations.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US 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 licensing fees, 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; <https://www.copyright.com/>. 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 10 years. When a document is more than 10 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](#) or [contact IEEE](#). For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website.

Errata

Errata, if any, for all IEEE standards can be accessed on the [IEEE SA Website](#). Search for standard number and year of approval to access the web page of the published standard. Errata links are located under the Additional Resources Details section. Errata are also available in [IEEE Xplore](#). Users are encouraged to periodically check for errata.

Patents

IEEE Standards are developed in compliance with the [IEEE SA Patent Policy](#).

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 <https://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.

IMPORTANT NOTICE

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. IEEE Standards development activities consider research and information presented to the standards development group in developing any safety recommendations. Other information about safety practices, changes in technology or technology implementation, or impact by peripheral systems also may be pertinent to safety considerations during implementation of the standard. 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.

Participants

At the time this revision was sent to sponsor ballot, the IEEE 802.11 Working Group (WG) had the following officers:

Dorothy V. Stanley, *Chair*
Jon W. Rosdahl, *1st Vice Chair*
Robert Stacey, *2nd Vice Chair*
Stephen McCann, *Secretary*

The officers of the WG Task Group and the members of the WG ballot group for this revision are as follows:

Dorothy V. Stanley, *Chair*
Mark Hamilton, *Vice Chair*
Michael Montemurro, *Vice Chair*
Jon W. Rosdahl, *Secretary*
Emily H. Qi, *Technical Editor*
Edward Au, *Technical Sub-editor*

Osama S. Aboulmagd
Tomoko Adachi
Jinsoo Ahn
Woojin Ahn
Kosuke Aio
Carlos H. Aldana
Yaron Alpert
Song-Haur An
Carol Ansley
Lee R. Armstrong
Yusuke Asai
Alfred Asterjadhi
Kwok Shum S. Au
Vijay Auluck
Geert A. Awater
Shahnaz Azizi
Robert Baeten
Eugene Baik
Stephane Baron
Anuj Batra
Friedbert Berens
Christian Berger
Nehru Bhandaru
John Buffington
George Calcev
Rui Cao
Laurent Cariou
William Carney
Ricky Chair
Clint F. Chaplin
Jiamin Chen
Xiaogang Chen
George Cherian
Dmitry Cherniavsky
Rojan Chitrakar
Hangyu Cho
Jinsoo Choi
Liwen Chu
Jinyoung Chun
Dana Ciochina

Sean Coffey
Carlos Cordeiro
Claudio da Silva
Subir Das
Rolf J. de Vegt
Pierre Debergh
Donald E. Eastlake
Peter Ecclesine
Richard Edgar
Marc Emmelmann
Vinko Erceg
Andrew Estrada
Ping Fang
Yonggang Fang
Xiang Feng
Norman Finn
Matthew J. Fischer
Michael Fischer
Shunsuke Fujio
Sho Furuichi
Ming Gan
Eduard Garcia Villegas
Chittabrata Ghosh
James P. Gilb
Tim Godfrey
Niranjan Grandhe
Michael Grigat
Qiang Guo
Yuchen Guo
Robert Hall
Xiao Han
Thomas Handte
Christopher J. Hansen
Chris Hartman
Victor Hayes
Allen D. Heberling
Ahmadreza Hedayat
Robert F. Heile
Guido R. Hiertz
Duncan Ho

Hanseul Hong
Koji Horisaki
Chunyu Hu
Lei Huang
Po-Kai Huang
Zhiyong Huang
Sung Hyun H. Hwang
Yasuhiko Inoue
Timothy Jeffries
Jia Jia
Jinjing Jiang
Liang Jin
Allan Jones
Vincent Knowles Jones
Volker Jungnickel
Christophe Jurczak
Carl W. Kain
Naveen K. Kakani
Dzevdan Kapetanovic
Assaf Y. Kasher
Oren Kedem
Richard H. Kennedy
Stuart J. Kerry
Evgeny Khorov
Jeongki Kim
Jin Min Kim
Sang Gook Kim
Suhwook Kim
Yongho Kim
Youhan Kim
Jarkko Knecht
Geonjung Ko
Fumihide Kojima
Bruce P. Kraemer
Manish Kumar
Rajesh Kumar
Massinissa Lalam
Zhou Lan
Leonardo Lanante
James Lansford

Jae Seung S. Lee	Minyoung Park	Bin Tian
Sungeun Lee	Sung-jin Park	Fei Tong
Suzanne Leicht	Glenn Parsons	Solomon B. Trainin
James Lepp	Abhishek Patil	Yoshio Urabe
Joseph Levy	Hakan Persson	Richard D. Van Nee
Dejian Li	James E. Petranovich	Allert Van Zelst
Guoqing Li	Albert Petrick	Lorenzo Vangelista
Huan-Bang Li	Ron Porat	Jerome Vanthournout
Qiang Li	Rethnakaran Pulikkoonattu	Prabodh Varshney
Yanchun Li	Dengyu Qiao	Ganesh Venkatesan
Yunbo Li	Demir Rakanovic	Lochan Verma
Dong Guk Lim	Enrico-Henrik Rantala	Sameer Vermani
Yingpei Lin	Maximilian Riegel	Pascal Viger
Erik Lindskog	Mark Rison	George A. Vlantis
Der-Zheng Liu	Zhigang Rong	Chao Chun Wang
Jianhan Liu	Kiseon Ryu	Haiming Wang
Yong Liu	Bahareh Sadeghi	Huizhao Wang
Peter Loc	Takenori Sakamoto	James June J. Wang
Artyom Lomayev	Kazuyuki Sakoda	Lei Wang
Hui-Ling Lou	Sam Sambasivan	Xiaofei Wang
Kaiying Lv	Hemanth Sampath	Xuehuan Wang
Lily Lv	Naotaka Sato	Lisa Ward
Jing Ma	Sigurd Schelstraete	Julian Webber
Narendar Madhavan	Andy Scott	Menzo M. Wentink
Jouni K. Malinen	Yongho Seok	Leif Wilhelmsson
Alexander Maltsev	Stephen J. Shellhammer	Eric Wong
Hiroshi Mano	Ian Sherlock	Tianyu Wu
Roger Marks	Shimi Shilo	Yan Xin
Stephen McCann	Graham K. Smith	Qi Xue
Simone Merlin	Ju-Hyung Son	Rui Yang
Apurva Mody	Sudhir Srinivasa	Xun Yang
Bibhu Mohanty	Robert Stacey	Yunsong Yang
Hitoshi Morioka	Adrian P. Stephens	Kazuto Yano
Yuichi Morioka	Noel Stott	James Yee
Hiroyuki Motozuka	Jung Hoon H. Suh	Peter Yee
Robert Mueller	Takenori Sumi	Su Khiong K. Yong
Yutaka Murakami	Bo Sun	Christopher Young
Andrew Myles	Chen Sun	Heejung Yu
Patrice Nezou	Li-Hsiang Sun	Jian Yu
Paul Nikolich	Sheng Sun	Mao Yu
Yujin Noh	YanJun Sun	SunWoong Yun
John Notor	Dennis Sundman	Alan Zeleznikar
Minseok Oh	Mineo Takai	Hongyuan Zhang
Oghenekome Oteri	Sagar Tamhane	Xingxin Zhang
Kazuyuki Ozaki	Yusuke Tanaka	Yan Zhang
Stephen Palm	Kentaro Taniguchi	Xiayu Zheng
Eunsung Park	Wu Tao	Lan Zhuo

Major contributions were received from the following individuals:

Tomo Adachi	Daniel N. Harkins	Mark Rison
Edward Au	Jerome Henry	Jon W. Rosdahl
Gabr Bajko	Guido R. Hiertz	Kazuyuki Sakoda
Nehru Bhandaru	Srinivas Kandala	Sigurd Schelstraete
Jiamin Chen	Assaf Y. Kasher	Graham K. Smith
Sean Coffey	Youhan Kim	Robert Stacey
Thomas Derham	Jouni K. Malinen	Dorothy V. Stanley
Peter Ecclesine	Stephen McCann	Bo Sun
Marc Emmelmann	Michael Montemurro	Payam Torab
Matthew J. Fischer	Yujin Noh	Solomon B. Trainin
David Goodall	Abhishek Patil	Ganesh Venkatesan
Mark Hamilton	Emily H. Qi	Haiming Wang
Christopher J. Hansen		Menzo M. Wentink

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

Osama Aboulmagd	Atsushi Ito	R. K. Rannow
Tomoko Adachi	Raj Jain	Ranga Reddy
Robert Aiello	SangKwon Jeong	Alon Regev
Thomas Alexander	Pranav Jha	Maximilian Riegel
Nobumitsu Amachi	Jeffrum Jones	Mark Rison
Carol Ansley	Joe Natharoj Juisai	Robert Robinson
Butch Anton	Lokesh Kabra	Benjamin Rolfe
Alfred Asterjadhi	Srinivas Kandala	Jon W. Rosdahl
Kwok Shum S. Au	Piotr Karocki	Kazuyuki Sakoda
Harry Bims	Assaf Y. Kasher	Stephan Sand
Nancy Bravin	Stuart J. Kerry	Chester Sandberg
Jason Brent	Evgeny Khorov	Shigenobu Sasaki
Vern Brethour	Yongbum Kim	Naotaka Sato
Demetrio Bucaneg	Youhan Kim	Sigurd Schelstraete
William Byrd	Patrick Kinney	Andy Scott
Paul Cardinal	Shoichi Kitazawa	Yongho Seok
William Carney	Jan Kruys	Kunal Shah
Juan Carreon	Yasushi Kudoh	Ian Sherlock
Pin Chang	Thomas Kurihara	Di Dieter Smely
Cheng Chen	Hyeong Ho Lee	Graham K. Smith
Evelyn Chen	Kang Lee	Robert Stacey
George Cherian	Wookbong Lee	Dorothy V. Stanley
Rojan Chitrakar	Frank Leong	Thomas Starai
Paul Chiuchiolio	James Lepp	Noel Stott
John Coffey	Joseph Levy	Walter Struppler
Charles Cook	Yong Liu	Mark Sturza
D. Nelson Costa	Javier Luiso	Mitsutoshi Sugawara
Claudio da Silva	Valerie Maguire	Bo Sun
Antonio de la Oliva Delgado	Jouni K. Malinen	Li-Hsiang Sun
Peter Ecclesine	Jeffery Masters	Jasja Tijink
Richard Edgar	Stephen McCann	Payam Torab Jahromi
Alecsander Eitan	Brett McClellan	Solomon B. Trainin
Marc Emmelmann	Michael Montemurro	Mark-Rene Uchida
Xiang Feng	Hiroyuki Motozuka	Allert Van Zelst
Matthew J. Fischer	Ronald Murias	Prabodh Varshney
Michael Fischer	Rick Murphy	John Vergis
Avraham Freedman	Andrew Myles	Lochan Verma
Sho Furuichi	Paul Neveux	George A. Vlantis
Devon Gayle	Nick S. A. Nikjoo	Lei Wang
Mariana Goldhamer	Paul Nikolich	Lisa Ward
David Goodall	Robert O'Hara	Hung-Yu Wei
Michael Gundlach	Satoshi Obara	Matthias Wendt
Mark Hamilton	Bansi Patel	Menzo M. Wentink
Christopher J. Hansen	Abhishek Patil	Scott Willy
Jerome Henry	Arumugam Paventhan	Andreas Wolf
Marco Hernandez	Albert Petrick	Chun Yu Charles Wong
Lili Hervieu	Brian Petry	Forrest Wright
Guido R. Hiertz	David Piehler	Peter Wu
Werner Hoelzl	Walter Pienciak	Yunsong Yang
Oliver Holland	Clinton Powell	Yu Yuan
Glenn Hu	Venkatesha Prasad	Oren Yuen
Yasuhiko Inoue	Emily H. Qi	Janusz Zalewski
	Demir Rakanovic	

When the IEEE SA Standards Board approved this recommended practice on 3 December 2020, it had the following membership:

Gary Hoffman, *Chair*
Jon Walter Rosdahl, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Ted Burse
Doug Edwards
J. Travis Griffith
Grace Gu
Guido R. Hiertz
Joseph L. Koepfinger*

David J. Law
Howard Li
Dong Liu
Kevin Lu
Paul Nikolich
Damir Novosel
Dorothy V. Stanley

Mehmet Ulema
Lei Wang
Sha Wei
Philip B. Winston
Daidi Zhong
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.11-2020, IEEE Standard for Information Technology—Telecommunications and Information Exchange between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

This revision gives users, in one document, the IEEE 802.11 standard for wireless local area networks (WLANs) with all of the amendments that have been published to date.

Incorporating published amendments

The original standard was published in 1997, revised in 1999 with MIB changes, and reaffirmed in 2003.

A revision was published in 2007, which incorporated into the 1999 edition the following amendments:

- IEEE Std 802.11aTM-1999: High-speed Physical Layer in the 5 GHz Band (Amendment 1)
- IEEE Std 802.11bTM-1999: Higher-Speed Physical Layer Extension in the 2.4 GHz Band (Amendment 2)
- IEEE Std 802.11b-1999/Corrigendum 1-2001: Higher-speed Physical Layer (PHY) extension in the 2.4 GHz band (Corrigendum 1 to Amendment 2)
- IEEE Std 802.11dTM-2001: Specification for operation in additional regulatory domains (Amendment 3)
- IEEE Std 802.11gTM-2003: Further Higher Data Rate Extension in the 2.4 GHz Band (Amendment 4)
- IEEE Std 802.11hTM-2003: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe (Amendment 5)
- IEEE Std 802.11iTM-2004: Medium Access Control (MAC) Security Enhancements (Amendment 6)
- IEEE Std 802.11jTM-2004: 4.9 GHz–5 GHz Operation in Japan (Amendment 7)
- IEEE Std 802.11eTM-2005: Medium Access Control (MAC) Quality of Service Enhancements (Amendment 8)

A revision was published in 2012, which incorporated into the 2007 revision the following amendments:

- IEEE Std 802.11kTM-2008: Radio Resource Measurement of Wireless LANs (Amendment 1)
- IEEE Std 802.11rTM-2008: Fast Basic Service Set (BSS) Transition (Amendment 2)
- IEEE Std 802.11yTM-2008: 3650–3700 MHz Operation in USA (Amendment 3)
- IEEE Std 802.11wTM-2009: Protected Management Frames (Amendment 4)
- IEEE Std 802.11nTM-2009: Enhancements for Higher Throughput (Amendment 5)
- IEEE Std 802.11pTM-2010: Wireless Access in Vehicular Environments (Amendment 6)
- IEEE Std 802.11zTM-2010: Extensions to Direct-Link Setup (DLS) (Amendment 7)
- IEEE Std 802.11vTM-2011: Wireless Network Management (Amendment 8)
- IEEE Std 802.11uTM-2011: Interworking with External Networks (Amendment 9)
- IEEE Std 802.11sTM-2011: Mesh Networking (Amendment 10)

A revision was published in 2016, which incorporated into the 2012 revision the following amendments:

- IEEE Std 802.11ae™-2012: Prioritization of Management Frames (Amendment 1)
- IEEE Std 802.11aa™-2012: MAC Enhancements for Robust Audio Video Streaming (Amendment 2)
- IEEE Std 802.11ad™-2012: Enhancements for Very High Throughput in the 60 GHz Band (Amendment 3)
- IEEE Std 802.11ac™-2013: Enhancements for Very High Throughput for Operation in Bands below 6 GHz (Amendment 4)
- IEEE Std 802.11af™-2013: Television White Spaces (TVWS) Operation (Amendment 5)

This revision is based on IEEE Std 802.11-2016, into which the following amendments have been incorporated:

- IEEE Std 802.11ai™-2016 (second printing): Fast Initial Link Setup (Amendment 1)
- IEEE Std 802.11ah™-2016: Sub 1 GHz License Exempt Operation (Amendment 2)
- IEEE Std 802.11aj™-2018: Enhancements for Very High Throughput to Support Chinese Millimeter Wave Frequency Bands (60 GHz and 45 GHz) (Amendment 3)
- IEEE Std 802.11ak™-2018: Enhancements for Transit Links Within Bridged Networks (Amendment 4)
- IEEE Std 802.11aq™-2018: Preassociation Discovery (Amendment 5)

Technical corrections, clarifications, and enhancements

In addition, this revision specifies technical corrections and clarifications to IEEE Std 802.11 as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. In addition, this revision removes some features previously marked as obsolete and adds new indications of other obsolete features.

Generally, features that are marked deprecated or obsolete are not maintained; there might be technical errors in the material describing these features.

idle power indicator (IPI): A physical layer (PHY) indication of the total channel power (noise and interference) as measured in the channel at the receiving antenna connector while the station (STA) is idle, i.e., neither transmitting nor receiving a frame.

IEEE 802.1X authentication: Extensible Authentication Protocol (EAP) authentication transported by the IEEE 802.1X protocol.

independent basic service set (IBSS): A basic service set (BSS) that forms a self-contained network, and in which no access to a distribution system (DS) is available.

independent basic service set (IBSS) station (STA): A STA that has started or joined an IBSS.

individual address: A medium access control (MAC) address in which the group bit is 0. *Syn:* **directed address, unicast address.**

individually addressed: When applied to a medium access control (MAC) service data unit (MSDU), it is an MSDU with an individual address as the destination address (DA). When applied to a MAC protocol data unit (MPDU), it is an MPDU with an individual address in the Address 1 field. *Syn:* **directed, unicast.**

infrastructure: An infrastructure comprises a distribution system (DS), one or more more access points (APs), zero or one portals, and zero or more mesh gates. It is also the logical location of distribution and integration service functions of an extended service set (ESS).

infrastructure authorization information: The information that specifies the access rights of the user of a non-access-point (non-AP) station (STA). This information might include the rules for routing the user traffic, a set of permissions about services that a user is allowed to access, quality-of-service (QoS) configuration information, or the accounting policy to be applied by the infrastructure.

integration service: The service that enables delivery of medium access control (MAC) service data units (MSDUs) between the distribution system (DS) and a local area network (LAN) (via a portal).

integrity group temporal key (IGTK): A random value, assigned by the broadcast/multicast source station (STA), which is used to protect group addressed medium access control (MAC) management protocol data units (MMPDUs) from that source STA.

link margin: Ratio of the received signal power to the minimum required by the station (STA). The STA might incorporate rate information and channel conditions, including interference, into its computation of link margin. The specific algorithm for computing the link margin is implementation dependent.

link metric: A criterion used to characterize the performance, quality, and eligibility of a link.

little endian: The concept that, for a given multi-octet numeric representation, the least significant octet has the lowest address.

liveness: A demonstration that the peer is actually participating in this instance of communication.

location subject local: The term used when a location request is for the location of the requesting station (STA), i.e., when the requesting STA asks, “Where am I?”

location subject remote: The term used when a location request is for the location of the reporting station (STA), i.e., when the requesting STA asks, “Where are you?”

location subject third party: The term used when the location request is for the location of a station (STA) other than the requesting STA or the requested STA, (i.e., when the requesting STA asks, “Where is he/she?”)

master session key (MSK): Keying material that is derived between the Extensible Authentication Protocol (EAP) peer and exported by the EAP method to the Authentication Server (AS).

NOTE—In this standard, this key is at least 64 octets in length.

medium access control (MAC) frame: The unit of data exchanged between MAC entities. *Syn:* **medium access control (MAC) protocol data unit (MPDU).**

NOTE—In contexts in which the MAC is clearly the subject, “frame” is an implicit reference to a MAC frame.

medium access control (MAC) protocol data unit (MPDU): The unit of data exchanged between two peer MAC entities using the services of the physical layer (PHY). *Syn:* **medium access control (MAC) frame.**

medium access control (MAC) service data unit (MSDU): Information that is delivered as a unit between MAC service access points (SAPs).

medium access control (MAC) service tuple: The collection of a MAC service data unit (MSDU) along with the associated source address, destination addresses, priority, drop eligibility, service class, optional set of service_access_point_identifiers, and optional indication of whether the supplied MSDU is in Ethernet protocol discrimination (EPD) or logical link control (LLC) protocol discrimination (LPD) format, which are all passed as parameters across the MAC service access point (SAP) and are all except the service_access_point_identifiers delivered across the distribution system between access points (APs), mesh gates, and the portal of an extended service set (ESS).

mesh basic service set (MBSS): A basic service set (BSS) that forms a self-contained network of mesh stations (STAs) that use the same mesh profile. An MBSS contains zero or more mesh gates, and can be formed from mesh STAs that are not in direct communication.

mesh facility: The set of enhanced functions, channel access rules, frame formats, mutual authentication methods, and managed objects used to provide data transfer among autonomously operating stations (STAs) that might not be in direct communication with each other over a single instance of the wireless medium. Communication between STAs using the mesh facility takes place using only the wireless medium. The mesh facility transports a medium access control (MAC) service data unit (MSDU) between source and destination STAs over potentially multiple hops of the wireless medium without transiting the MAC service access point (SAP) at intermediate STAs.

mesh gate: Any entity that has a mesh station (STA) function and a distribution system access function (DSAF) to provide access to a single distribution system for the mesh basic service set (MBSS).

mesh link: A link from one mesh station (STA) to a neighbor mesh STA that have a mesh peering with each other.

mesh neighborhood: The set of all neighbor mesh stations (STAs) of a particular mesh STA.

mesh path: A concatenated set of mesh links from a source mesh station (STA) to a destination mesh STA.

mesh path selection: The process of selecting a mesh path.

mesh peering: A relationship between two mesh stations (STAs) that is required for direct communication over a single instance of the wireless medium (WM). A mesh peering is established with a mesh peering protocol.

mesh profile: A set of values of parameters that identifies the attributes of the mesh basic service set (MBSS) and that is used in a single MBSS.

NOTE—The mesh profile consists of the identifiers that are the values for the parameters: mesh identifier (ID), active path selection protocol, active path selection metric, congestion control mode, synchronization method, and authentication protocol.

mesh services: The set of services that enable the creation and operation of a mesh basic service set (MBSS).

mesh station (STA): A quality-of-service (QoS) STA that implements the mesh facility.

message integrity code (MIC): A value generated by a cryptographic function. If the input data are changed, a new value cannot be correctly computed without knowledge of the cryptographic key(s) used by the cryptographic function.

NOTE—This is traditionally called a *message authentication code* (MAC), but the acronym MAC is already reserved for another meaning in this standard.

mobile station (STA): A type of STA that uses network communications while in motion.

mobility domain: A set of basic service sets (BSSs), within the same extended service set (ESS), that support fast BSS transitions between themselves and that are identified by the set's mobility domain identifier (MDID).

mobility domain identifier (MDID): An identifier that names a mobility domain.

multicast: *See: group addressed.*

multicast address: *See: group address.*

multicast-group address: A medium access control (MAC) address associated by higher level convention with a group of logically related stations (STAs).

multi-level precedence and preemption (MLPP): A framework used with admission control for the treatment of traffic streams based on precedence, which supports the preemption of an active traffic stream by a higher precedence traffic stream when resources are limited. Preemption is the act of forcibly removing a traffic stream in progress in order to free up resources for another higher precedence traffic stream.

multiple basic service set identifier (BSSID) capability: The capability to advertise information for multiple BSSIDs using a single Beacon or Probe Response frame instead of using multiple Beacon or Probe Response frames, each corresponding to a single BSSID, and the capability to indicate buffered frames for these multiple BSSIDs using a single traffic indication map (TIM) element in a single Beacon or TIM frame.

multiple input, multiple output (MIMO): A physical layer (PHY) configuration in which both transmitter and receiver use multiple antennas.

multiple medium access control (MAC) station management entity (SME) (MM-SME): Component of station management that manages multiple cooperating stations (STAs).

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE Std 802.11 supports only downlink (DL) MU-MIMO. *See* downlink multi-user multiple input, multiple output (DL-MU-MIMO) (in 3.2).

neighbor access point (AP): Any AP that is a potential service set transition candidate.

neighbor station (STA): A STA in the following relationship: STA A is a neighbor to STA B if STA A can both directly transmit to and receive from STA B over the wireless medium.

network access identifier (NAI): The user identity submitted by the Supplicant during IEEE 802.1X authentication.

NOTE—See IETF RFC 4282.

network access server (NAS) client: The client component of a NAS that communicates with the Authentication Server (AS).

network allocation vector (NAV): An indicator, maintained by each station (STA), of time periods when transmission onto the wireless medium (WM) is not initiated by the STA regardless of whether the STA's clear channel assessment (CCA) function senses that the WM is busy.

next-hop mesh station (STA): The next peer mesh STA on the mesh path to the destination mesh STA.

non-access-point (non-AP) station (STA): A STA that is not contained within an access point (AP).

nonce: A numerical value, used in cryptographic operations associated with a given cryptographic key, that is not to be reused with that key, including over all reinitializations of the system through all time.

noncontiguous transmission: A transmission that uses nonadjacent frequency segments.

nonoperating channel: A channel that is not the operating channel of the basic service set (BSS) of which the station (STA) is a member.

non-quality-of-service (non-QoS) access point (AP): An AP that does not support the quality-of-service (QoS) facility.

non-quality-of-service (non-QoS) basic service set (BSS): A BSS that does not support the quality-of-service (QoS) facility.

non-quality-of-service (non-QoS) station (STA): A STA that does not support the quality-of-service (QoS) facility.

operating channel: The operating channel is the channel in which beacons are transmitted.

NOTE—In IEEE Std 802.11, the serving access point (AP) of an infrastructure basic service set (BSS) or the dynamic frequency selection (DFS) owner of an independent basic service set (IBSS) transmits beacons.

operating channel width: The channel width in which the station (STA) is currently able to receive.

overlapping basic service set (OBSS): A basic service set (BSS) operating on the same channel as the station's (STA's) BSS and within (either partly or wholly) its basic service area (BSA).

over-the-air fast basic service set (BSS) transition (FT): An FT method in which the station (STA) communicates over a wireless medium (WM) link to the target access point (AP).

over-the-DS (distribution system) fast basic service set (BSS) transition (FT): An FT method in which the station (STA) communicates with the target access point (AP) via the current AP.

pairwise: Referring to, or an attribute of, two entities that are associated with each other, e.g., an access point (AP) and an associated station (STA), or two STAs in an independent basic service set (IBSS) network. This term is used to refer to a type of encryption key hierarchy pertaining to keys shared by only two entities.

pass-phrase: A secret text string employed to corroborate the user's identity.

password: A shared, secret, and potentially low-entropy word, phrase, code, or key used as a credential for authentication purposes.

NOTE—The method of distribution of a password to the units in the system is outside the scope of this standard.

path metric: An aggregate multi-hop criterion used to characterize the performance, quality, and eligibility of a mesh path.

peer mesh station (STA): A mesh STA to which a mesh peering has been established.

peer-to-peer link: A direct link within a quality-of-service (QoS) basic service set (BSS), a tunneled direct-link setup (TDLS) link, or a station-to-station (STA-to-STA) communication in an independent basic service set (IBSS).

peer-to-peer traffic specification (PTP TSPEC): The quality-of-service (QoS) characteristics of a data flow between non-access point (non-AP) QoS stations (STAs).

perfect forward secrecy (PFS): A property of a key agreement protocol that protects a session key derived from a set of long-term public and private keys from being compromised if one of the (long-term) private keys is compromised in the future.

per-frame encryption key: A unique encryption key constructed for each medium access control (MAC) protocol data unit (MPDU).

physical layer (PHY) frame: The unit of data exchanged between PHY entities. *Syn:* **physical layer (PHY) protocol data unit (PPDU).**

NOTE—In contexts in which the PHY is clearly the subject, “frame” is an implicit reference to a PHY frame.

physical layer (PHY) protocol data unit (PPDU): The unit of data exchanged between two peer PHY entities to provide the PHY data service.

piggyback: The overloading of data with an acknowledgment of a previously received frame to the station (STA) to which the data is directed.

portable station (STA): A type of station (STA) that might be moved from location to location, but that uses network communications only while at a fixed location.

portal: The logical point at which the integration service is provided.

NOTE—For the purposes of this Standard, there is at most one portal in a given extended service set's (ESS's) infrastructure. In an implementation, a single logical portal function may be provided by multiple devices that provide integration services for the ESS. How such multiple devices coordinate to appear as a single logical portal is implementation dependent.

precursor mesh station (STA): A neighbor peer mesh STA on the mesh path to the destination mesh STA, that identifies the mesh STA as the next-hop mesh STA.

preshared key (PSK): A static key that is distributed to the units in the system by some out-of-band means.

primary channel: The common channel of operation for all stations (STAs) that are members of the basic service set (BSS). For example, in a 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz BSS the primary channel is a primary 20 MHz channel.

prioritized quality of service (QoS): The provisioning of service in which the medium access control (MAC) protocol data units (MPDUs) with higher priority are given a preferential treatment over MPDUs with a lower priority.

NOTE—Prioritized QoS is provided through the enhanced distributed channel access (EDCA) mechanism.

protection mechanism: Any procedure that attempts to update the network allocation vector (NAV) of all receiving stations (STAs) prior to the transmission of a frame that might or might not be detected as valid network activity by the physical layer (PHY) entities at those receiving STAs.

protection mechanism frame: Any frame that is sent as part of a protection mechanism procedure.

protocol instance: An execution of a particular protocol that consists of the state of the communicating parties as well as the messages exchanged.

proxy mesh gate: A mesh gate acting as an intermediary for IEEE 802 stations (STAs) outside the mesh basic service set (MBSS).

pseudorandom function (PRF): A function that hashes various inputs to derive a pseudorandom value. In order to ensure liveness of a communication in which a pseudorandom value is used, a nonce is used as one of the inputs to the function.

public safety answering point (PSAP): A physical location where emergency calls are received and routed to the appropriate emergency service dispatch center.

NOTE—See NENA 08-002 [B57].

quadrature binary phase shift keying (QBPSK): A binary phase shift keying modulation in which the binary data is mapped onto the imaginary (Q) axis.

quality-of-service (QoS) access point (AP): An AP that supports the QoS facility.

NOTE—In IEEE Std 802.11, the functions of a QoS AP are a superset of the functions of a non-QoS AP, and thus a QoS AP is able to function as a non-QoS AP to non-QoS stations (STAs).

quality-of-service (QoS) basic service set (BSS): A BSS that provides the QoS facility. An infrastructure QoS BSS contains a QoS access point (AP).

quality-of-service (QoS) facility: The set of enhanced functions, channel access rules, frame formats, frame exchange sequences and managed objects used to provide parameterized and prioritized QoS.

quality-of-service (QoS) independent basic service set (IBSS): An IBSS in which one or more of its stations (STAs) support the QoS facility.

quality-of-service (QoS) station (STA): A STA that implements the QoS facility.

NOTE—A QoS STA acts as a non-QoS STA when associated in a non-QoS basic service set (BSS).

radio frequency (RF) chain: The physical entity that is able to act as a receive chain or transmit chain, or both.

reassociation service: The service that enables an established association [between access point (AP) and station (STA)] to be transferred from one AP to another (or the same) AP.

receive chain: The physical entity that implements any necessary signal processing to provide the received signal to the digital baseband. Such signal processing includes filtering, amplification, down-conversion, and sampling.

receive power: Mean power measured at the antenna connector.

received channel power indicator (RCPI): An indication of the total channel power (signal, noise, and interference) of a received frame measured on the channel and at the antenna connector used to receive the frame.

received power indicator (RPI): A quantized measure of the received power level as seen at the antenna connector.

registered location: The geolocation of a station (STA) registered in accordance with the requirements for the regulatory domain.

registered location query protocol (RLQP): The query protocol for registered location information that is received and transported by generic advertisement service (GAS) Public Action frames.

registered location secure server (RLSS): An entity that accesses and manages a database that organizes storage of information by geographic location and securely holds the location and some operating parameters of one or more basic service sets (BSSs).

registered station (STA): A STA for which information needs to be submitted to an appropriate regulatory or coordination authority before it is allowed to transmit.

remote request broker (RRB): The component of the station management entity (SME) of an access point (AP) that supports fast basic service set (BSS) transitions over the distribution system (DS).

roaming consortium: A group of subscription service providers (SSPs) having inter-SSP roaming agreements.

service hash: A value used for representing a service. This value is formed from a hash of the service name.

service set identifier (SSID): A string used to identify the infrastructure basic service sets (BSSs) that comprise an extended service set (ESS), or to identify a non-infrastructure BSS.

service set transition: A station (STA) movement from one basic service set (BSS) to another BSS, i.e., either a BSS transition or an extended service set (ESS) transition.

serving access point (AP): The AP to which the station (STA) is associated.

single-user multiple input, multiple output (SU-MIMO): A technique by which a station (STA) with more than one antenna either transmits to or receives from a single STA independent space-time streams over the same radio frequencies.

single-user (SU) physical layer (PHY) protocol data unit (PPDU): A PPDU with a format that is capable of carrying only a single PHY service data unit (PSDU), or no PSDU.

sounding: The use of preamble training fields to measure the channel for purposes other than demodulation of the Data portion of the physical layer (PHY) protocol data unit (PPDU) containing the training fields.

NOTE—These uses include calculation of transmit steering, calculation of recommended modulation and coding scheme (MCS), and calculation of calibration parameters.